COMPTES RENDUS
(DOKLADY)
DE L'ACADÉMIE DES SCIENCES DE L'URSS

NOUVELLE SÉRIE

1939

IMPERIAL MYCOLOGICAL
6 MAR. 1940
INSTITUTE

VOLUME XXV

№ 8

ÉDITION DE L'ACADÉMIE DES SCIENCES DE L'URSS
MOSCOU

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NOUVELLE SÉRIE

7-me année

Paraissant tous les dix jours

1939

VOLUME XXV, № 8

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En composition 29/XI 1939. En impression 19/XII 1939. Nombre de feuilles d'impression 4 1/2. Nombre de caractères par feuille d'impression 65.000. Pages 641—712. Format du papier 72×110 cm. Tirage 1000. Glavlit A 15978. Numéro d'édition 2094. Numéro typographique 2361.

Imprimerie № 16. Moscou, Trekhproudnij péréoulok, 9.

Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1939. Volume XXV, № 8

MATHÉMATIQUES

SUR LES FONCTIONS DE GREEN NON-SYMÉTRIQUES OSCILLATOIRES DES OPÉRATEURS DIFFÉRENTIELS ORDINAIRES

Par M. KREIN

(Présenté par S. N. Bernstein, de l'Académie, le 25. X. 1939)

Les résultats que nous allons exposer présentent une généralisation et un développement ultérieur de nos recherches précédentes relatives aux fonctions de Green oscillatoires [1,2]. Ces résultats permettent d'établir des théorèmes d'oscillation (analogues aux théorèmes classiques de Sturm) pour une classe étendue de problèmes limites indépendamment de ce que ces problèmes soient autoadjoints ou non et de leur ordre.

1. Soit

$$L(y)=\sum_{k=0}^{n} l_k(x)\frac{d^k y}{dx^k} \quad (n\geqslant 2)$$

un opérateur différentiel autoadjoint dont les coefficients sont des fonctions continues dans l'intervalle fermé (a, b) et soit

$$l_n(x)>0 \quad \text{pour} \quad a\leqslant x\leqslant b.$$

Soit $G(x,s)\,(a\leqslant x,\ s\leqslant b)$ une fonction de Green de l'opérateur $L(y)$. Il est connu que cette fonction admet la représentation suivante:

$$G(x,s)=\begin{cases}\sum\limits_{j=1}^{q}\psi_j(x)\chi_j(s) & (x\leqslant s)\\ \sum\limits_{j=1}^{p}\psi_j^*(x)\chi_j^*(s) & (x\geqslant s)\end{cases} \tag{1}$$

où les fonctions $\psi_1(x),\ldots,\psi_q(x)$, ainsi que les fonctions $\psi_1^*(x),\ldots,\psi_p^*(x)$, sont des solutions linéairement indépendantes de l'équation homogène $L(y)=0$ et $p+q\geqslant n$.

Dans les théorèmes qui suivent il s'agit des fonctions de Green $G(x,s)$ de l'opérateur $L(y)$ telles que $\varepsilon G(x,s)$ $(\varepsilon=\pm 1)$ est un noyau oscillatoire [voir la définition de noyau oscillatoire dans la Note de l'auteur [2] ou dans la Note de Krein-Finkelstein [3], où l'on a donné une autre définition, mais équivalente à celle de cette Note].

Théorème 1. *Si* $\varepsilon G(x,s)$ $(\varepsilon=\pm 1)$ *est un noyau oscillatoire, on a* $\varepsilon=(-1)^q$ *et* $p+q=n$ *.

* D'ailleurs, $p, q>1$ [voir la Note [3]].

En effet, si $\varepsilon G(x,s)$ est un noyau oscillatoire admettant la représentation (1), on a d'après le théorème de Krein-Finkelstein [3]:

$$\varepsilon^n G\begin{pmatrix} x_1 x_2 \dots x_m \\ s_1 s_2 \dots s_m \end{pmatrix} > 0 \quad \left(a < \begin{matrix} x_1 < x_2 < \dots < x_n \\ s_1 < s_2 < \dots < s_n \end{matrix} < b\right)$$

à condition que

$$x_i < s_{i+p}\,(i=1,2,\dots m-q), \qquad s_i < x_{i+q}\,(i=1,2,\dots,n-p).$$

En particulier, on a

$$\varepsilon^{p+q} G\begin{pmatrix} x_1 x_2 \dots x_{p+q} \\ s_1 s_2 \dots s_{p+q} \end{pmatrix} > 0 \quad \text{pour} \quad a < s_1 < s_2 < \dots < s_p < x_1 < x_2 < \dots$$
$$\dots < x_{p+q} < s_{p+1} < \dots < s_{p+q} < b.$$

Or, la dernière inégalité montre que les $p+q$ fonctions $\psi_1, \psi_2, \dots \psi_q$, $\psi_1^*, \psi_2^*, \dots, \psi_p^*$ sont linéairement indépendantes. D'où $p+q \leqslant n$, et comme, d'autre part, $p+q \geqslant n$, on a $p+q=n$.

L'égalité $\varepsilon=(-1)^q$ exige des considérations plus compliquées, et nous sommes obligés de les omettre.

Comme il est aisé de voir, l'égalité $p+q=n$ indique que la fonction de Green $G(x,s)$ correspond à un système de conditions aux limites qu'on peut représenter sous la forme suivante:

$$\left.\begin{aligned} &\sum_{k=0}^{n-1} \alpha_{ik} y^{(k)}(a) = 0 \qquad (i=1,2,\dots p) \\ &\sum_{k=0}^{n-1} \beta_{ik} y^{(k)}(b) = 0 \qquad (i=1,2,\dots q) \end{aligned}\right\} \tag{2}$$

Ainsi, si une fonction de Green $G(x,s)$ multipliée par $\varepsilon = \pm 1$ devient un noyau oscillatoire, elle correspond à un système de conditions aux limites de la forme (2). C'est P. D. Kalafati qui a attiré l'attention de l'auteur sur ce fait et qui l'a obtenu indépendamment et par une méthode très compliquée.

En développant un peu les méthodes que l'auteur a exposées dans ses Notes précédentes [1,2,4], on peut établir les théorèmes suivants.

Théorème 2. *Si les conditions aux limites* (2) *sont non-singulières et la fonction de Green qui leur correspond multipliée par* $(-1)^q$ *est un noyau oscillatoire, les conditions aux limites*

$$\left.\begin{aligned} &y^{(i)}(a) = 0 \qquad (i=0,1,\dots p-1) \\ &\sum_{k=0}^{n-1} \beta_{ik} y^{(k)}(a) = 0 \qquad (i=1,2,\dots q) \end{aligned}\right\} \tag{3}$$

possèdent les mêmes propriétés.

La fonction de Green correspondant aux conditions (3) sera désignée par $G^{(p)}(x,s)$. On peut échanger les rôles des extrémités a et b dans le théorème 2. Donc, on a le

Corollaire. *Si les conditions aux limites* (2) *vérifient les conditions du théorème* 2, *les conditions aux limites*

$$y(a)=y'(a)=\dots=y^{(p-1)}(a)=0, \qquad y(b)=y'(b)=\dots=y^{(q-1)}(b)=0 \tag{4}$$

sont non-singulières et la fonction de Green $G^{(p,q)}(x,s)$ *qui leur correspond multipliée par* $(-1)^q$ *est un noyau oscillatoire.*

On a le critère suivant pour que $(-1)^q G^{(p,q)}(x,s)$ soit un noyau oscillatoire.

Théorème 3. *Le système des conditions aux limites* (4) $(1 \leqslant p < n)$ *étant non-singulier, le noyau* $G^{(p,q)}(x,s)$ *correspondant à ce système est un noyau oscillatoire dans le cas et dans ce cas seulement, où les deux conditions suivantes sont remplies:*

1°. *Le système différentiel*

$$L(y)=0, \qquad y(b)=y'(b)=\ldots=y^{(q-1)}(b)=0$$

a p solutions $\omega_1(x), \omega_2(x), \ldots, \omega_p(x)$ *telles que*

$$\omega_1>0,\ W(\omega_1,\omega_2)>0,\ \ldots,\ W(\omega_1,\omega_2,\ldots,\omega_p)>0 \text{ pour } a<x<b.$$

2°. *Le système différentiel*

$$L(y)=0, \qquad y(a)=y'(a)=\ldots=y^{(p-1)}a=0$$

a q solutions $\omega_{p+1}, \ldots, \omega_n$ *telles que*

$$W(\omega_1,\ldots,\omega_p,\omega_{p+1})>0,\ \ldots,\ W(\omega_1,\ldots,\omega_q,\ldots,\omega_n)>0 \text{ pour } a<x<b.$$

Observons que si les fonctions $\omega_1, \ldots, \omega_n$ satisfaisant aux conditions 1°, 2° existent, on peut les obtenir d'après la règle suivante. On prend pour $\omega_k(x)$ $(k=1,2,\ldots p)$ une solution arbitraire du système différentiel

$$L(y)=0, \quad y(b)=\ldots=y^{(q-1)}(b)=0$$
$$y(a)=y'(a)=\ldots=y^{(p-k-1)}(a)=0, \qquad (-1)^{(n+k-1)}y^{(p-k)}(a)>0$$

et pour $\omega_{p+k}(x)$ $(k=1,2,\ldots q)$ une solution arbitraire du système différentiel

$$L(y)=0, \qquad y(a)=\ldots=y^{(p-1)}(a)=0$$
$$y(b)=y'(b)=\ldots=y^{(q-k-1)}(b)=0, \qquad (-1)^{p+k}y^{(p-k)}(a)>0.$$

Théorème 4. *Les conditions* 1°, 2° *du théorème* 3* *sont équivalentes à cette seule condition, que l'opérateur* $L(y)$ *admette à l'intérieur de l'intervalle* (a,b) *la représentation suivante:*

$$L(y)=\rho_0\frac{d}{dx}\rho_1\frac{d}{dx}\rho_2\ldots\frac{d}{dx}\rho_n y \tag{5}$$

où $\rho_k(x)$ $(k=0,1,\ldots,n)$ *sont des fonctions positives possédant k dérivées continues à l'intérieur de l'intervalle* (a,b).

Il résulte du théorème 4 que si pour un p quelconque le noyau $(-1)^p G^{(p,q)}(x,s)$ est oscillatoire, il en est de même pour tout autre p $(1 \leqslant p < n)$, pour lequel la fonction de Green $G^{(p,q)}(x,s)$ existe [c'est-à-dire les conditions aux limites (4) sont non-singulières].

Théorème 5. *Pour qu'il existe pour tout* p $(1 \leqslant p < n)$ *une fonction de Green* $G^{(p,q)}(x,s)$ *telle que, étant multipliée par* $(-1)^q$, *elle devient un noyau oscillatoire, il faut et il suffit que l'opérateur* $L(y)$ *admette dans l'intervalle fermé* (a,b) *la représentation* (5), *où* $\rho_k(x)$ $(k=0,1,\ldots,n)$ *sont des fonctions positives ayant k dérivées continues dans l'intervalle fermé* (a,b).

2. Soit comme ci-dessus $G(x,s)$ une fonction de Green de l'opérateur $L(y)$, correspondant à un système de conditions aux limites de la forme (2) et telle que $(-1)^q G(x,s)$ est un noyau oscillatoire. Envisageons l'équation intégrale

$$\varphi(x)=\lambda\int_a^b G(x,s)\varphi(s)\,d\sigma(s),$$

* Le système des conditions (4) étant supposé non-singulier.

où $\sigma(x)$ est une fonction non-décroissante à une infinité de points de croissance.

Cette équation possède toutes les propriétés d'oscillation que nous avons autrefois signalées pour le cas des noyaux oscillatoires symétriques (2) [voir à ce sujet la Note de F. Gantmacher (5), où l'auteur a considéré l'équation intégrale à noyau de Kellogg non-symétrique et où la fonction $\sigma(x)$ est essentiellement croissante].

En particulier, les valeurs caractéristiques de l'équation (5) sont des racines simples du déterminant de Fredholm correspondant et ont toutes le même signe que $(-1)^q$. Donc, en les désignant convenablement par $\lambda_0, \lambda_1, \lambda_2, \ldots$, on a

$$0 < (-1)^q \lambda_0 < (-1)^q \lambda_1 < (-1)^q \lambda_2 < \ldots$$

En remplaçant dans l'équation (5) le noyau $G(x, s)$ par le noyau $G^{(p)}(x, s)$ (dont la définition est donnée immédiatement après le théorème 2) ou par le noyau $G^{(p, q)}(x, s)$, on obtient des nouvelles suites $\lambda_i^{(p)} (i = 0, 1, 2, \ldots)$ ou $\lambda_i^{(p, q)} (i = 0, 1, 2, \ldots)$ respectivement.

Théorème 6. *Les nombres* $\lambda_i, \lambda_i^{(p)} (i = 0, 1, 2, \ldots)$ *sont liés entre eux par les inégalités*

$$(-1)^q \lambda_i < (-1)^q \lambda_i^{(p)} < (-1)^q \lambda_{i+p} \quad (i = 0, 1, 2, \ldots).$$

Comme par analogie

$$(-1)^q \lambda_i^{(p)} < (-1)^q \lambda_i^{(p, q)} < (-1)^q \lambda_{i+q}^{(p)} \quad (i = 0, 1, 2, \ldots)$$

l'on a

$$(-1)^q \lambda_i < (-1)^q \lambda_i^{(p, q)} < (-1)^q \lambda_{i+n} \quad (i = 0, 1, 2 \ldots)$$

Le nombre p étant fixé, ces inégalités expriment une propriété extrémale du système de conditions (4), comparé avec tous les systèmes de conditions aux limites possibles de la forme (2), et dont les fonctions de Green étant multipliées par $(-1)^q$ sont des noyaux oscillatoires.

Pour terminer indiquons encore que les méthodes de la démonstration des théorèmes 2—5 sont, en général, les mêmes que l'auteur a employées dans ses recherches précédentes. Pour établir le théorème 6 l'auteur a été obligé d'introduire des considérations essentiellement nouvelles et d'établir préalablement quelques théorèmes généraux sur les noyaux de Kellogg non-symétriques.

Université d'État.
Odessa.

Manuscrit reçu
le 26.X.1939.

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Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1939. Volume XXV, № 8

THÉORIE DE L'ÉLASTICITÉ

UNE MÉTHODE D'EMPLOI DE MATIÈRES AUXILIAIRES POUR L'EXAMEN DES CONSTRUCTIONS COMPLEXES DANS LA LUMIÈRE POLARISÉE

Par E. V. POPOVA

(Présenté par S. A. Tchaplyguine, de l'Académie, le 6. X. 1939)

Afin d'éviter les difficultés, surgissant au cours des examens de modèles des constructions complexes dans la lumière polarisée, nous proposons la méthode qui consiste à introduire dans la construction de ces modèles une matière auxiliaire.

On a, d'après la loi bien connue, trouvée par Wertheim, pour tous les corps amorphes transparents à l'état de tension en tout point

$$\delta = ke(\sigma_1 - \sigma_2)$$

où δ désigne la différence de marche des rayons dans le point donné, e—l'épaisseur du modèle étudié et k—la constante optique de la matière dont est fait le modèle. Pour de différentes matières employées pour l'exécution des modèles, la valeur δ, dans les mêmes conditions de charge, sera différente suivant l'activité optique de la matière.

Comme toute étude optique est basée sur les perceptions de l'oeil, il se peut que la matière choisie ait une constante optique k telle que la différence de marche, résultant du passage des rayons lumineux à travers cette matière, sera pour toute valeur de la charge inférieure à ce que l'oeil peut distinguer. Examinée dans la lumière polarisée une telle matière va nous paraître inactive au point de vue optique pour des charges extérieures correspondantes.

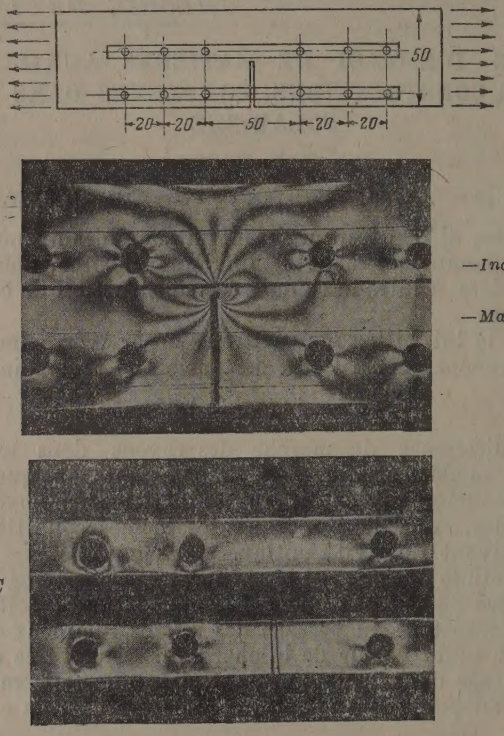
Cela nous a conduit à exécuter les modèles des constructions complexes avec deux matières différentes. La partie du modèle qu'on se propose d'étudier doit être faite avec la matière active au point de vue optique, tandis que le reste du modèle est exécuté avec une matière transparente, non-active. Alors le modèle examiné, étant éclairé par la lumière polarisée, nous paraîtra comme transparent et décoloré, tandis que la partie à étudier, exécutée avec de la matière active au point de vue optique, sera marquée de franges d'interference, et par suite il sera possible d'y étudier le champ de tension.

Cette méthode permet d'obtenir dans la lumière polarisée la résolution de problèmes de toute une classe, comme, par exemple, toute sorte d'éléments plans, fixés par des plaques, ou les détails gauffrés des diverses constructions à plusieurs couches et d'autres que l'on rencontre dans tous les domaines de l'industrie.

Comme, à notre connaissance, la méthode décrite n'a été nulle part employée, nous l'avons, en la proposant, surnommée «la méthode d'introduction de la matière auxiliaire».

On trouve dans la littérature les indications sur la possibilité d'utiliser dans la résolution du problème à trois dimensions le verre inactif de Pokels (1), mais cette proposition, sans avoir jamais été réalisée, a été même mise en doute (2). En tout cas cette proposition n'est pas en rapport direct avec la méthode créée et appliquée par notre laboratoire.

Le premier pas à faire vers la réalisation de l'examen des modèles complexes fut le choix d'une matière auxiliaire transparente, inactive au point de vue optique, et qui se distinguerait peu par ses propriétés méca-



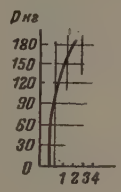
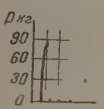
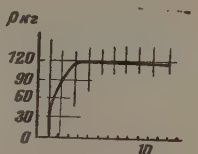
niques de la matière fondamentale, active au point de vue optique. Parmi les échantillons des matières plastiques soumis à notre examen nous avons choisi celui qui, à notre avis, satisfaisait le plus nos exigences.

Nous donnons plus bas dans la table les résultats des essais mécaniques de cette matière. On y trouvera de même les caractéristiques correspondantes des matières optiquement actives*.

Il suit de la courbe et de la table que l'échantillon choisi, dans l'intervalle où l'on effectue généralement les études dans la lumière polarisée, se comporte tout comme celluloïde ou bien marblette, c'est-à-dire comme une matière optiquement active.

Les propriétés optiques de la matière ont été mises à l'épreuve à l'aide de l'appareil de Koker. On n'observait, au cours de l'extension de l'échantillon, aucun éclaircissement, et seulement pour les charges, voisines de la charge de destruction, l'échantillon commenca à s'éclaircir. Au moment

* Les essais ont été effectués dans le laboratoire de la mécanique de bâtiments de l'Académie de l'Air.

	Matière	Inactine	Marblette	Celluloïde
Machine à essai de Schopper; charge limite 1000 kg	Courbes de destruction	Charge 	Charge 	Charge 
	Dimensions de la section de l'échantillon (mm)	2.5×15	3×15	2×15
Machine à essai de Amsler; charge limite 2000 kg (échelle 200 kg)	Module de l'élasticité normale	$E=2.26\times10^4$	$E=2.15\times10^4$	$E=2.26\times10$
		les mesures ont été effectuées avec un extensiomètre à miroir de Martens		
	Coefficient de Poisson	$\mu=0.415$	$\mu=0.408$	$\mu=0.396$
		les mesures ont été effectuées avec un tensiomètre de Hugenberger		

de la destruction la différence de marche devenait considérable, ce qu'on pouvait distinguer par la brillance de l'échantillon dans le champ foncé de l'appareil. Nous n'avons, par conséquent, trouvé aucune différence essentielle entre les propriétés de l'échantillon essayé et les matières utilisables pour l'étude optique des tensions. De là le nom donné à la matière de l'échantillon—«inactine», ce qui veut dire «inactif».

La méthode trouvée a été appliquée à la résolution des problèmes fondamentaux de notre section, à savoir, à l'étude de l'état tendu des éléments contenant des soutiens.

Les détails exécutés en inactine se sont très bien comportés et n'ont donné aucun signe d'activité optique sensible à l'oeil, ce qui a permi d'observer sans obstacles toutes les régions à étudier. On a pu photographier directement dans le faisceau des rayons polarisés les champs des isochromes, séparément pour les éléments de renfort et les modèles fondamentaux (fig. 1).

Il est évident qu'on pourra aussi obtenir par la même méthode la résolution de quelques problèmes à trois dimensions. Les expériences de ce genre ont été déjà commencées dans notre laboratoire. Leur description fera sujet d'une Note spéciale.

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Manuscrit reçu
le 22.X.1939.

LITTÉRATURE CITÉE

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Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1939. Volume XXV, № 8

PHYSICS

ON THE RADIATIVE STOPPING (BREMSESTRAHLUNG) OF FAST ELECTRONS IN THIN LAYERS

By L. ARTZIMOVICH and M. BREDOV

(Communicated by A. F. Joffé, Member of the Academy, 29. X. 1939)

Up to the present, the investigations into the radiative stopping of fast electrons possessing an energy of the order of several millions of volts have been restricted to thick layers of matter, and the integral intensity has been measured of the radiation produced along the path of the electron prior to its being stopped. Measurements of this kind are not likely to throw any direct light on the elementary act of radiative stopping; it would therefore be of interest to extend them to thin layers of matter where the individual collisions between electrons and atoms do not interfere and manifest themselves independently. Such experiments will also yield direct data on the effective cross-section of the elementary action of stopping.

The present note contains the results of a study of the radiative stopping of electrons with an energy of 1 and 2 MV in Al, Cu, Sn and Pb foils.

A preparation of Ra emanation served as a source of electrons. A narrow beam of electrons was obtained by means of an electron spectrograph with double focusing in a longitudinal magnetic field ([1]), the accuracy of monochromatization attained $\pm 2\%$ of the whole focused energy. The diameter of the focusing spot was 10 mm, the cone of spread of the electron beam constituted 15°.

The target, in which the radiative stopping had to be examined, was placed immediately behind the window of the spectrograph. The respective thicknesses of the foils were chosen of approximately equivalent scattering power; thus, the variation of the intensity of the radiation with the atomic number was in no way influenced by the angular spread of the electron beam. An exception had to be made for aluminium, for which the calculated thickness worked out too large.

When passing through a thin target, the electrons lose only a small fraction of their initial energy and must be further either deviated by a magnetic field, or made to be absorbed in some light substance. the low atomic number of the absorber being essential to guarantee a less intense background due to the stopping in the absorber. The first method considerably complicates the experimental conditions for the measurement; we therefore used a 1.5 cm paraffin block (effective atomic number 4.2) placed close to the target, though there was the inconvenience of a rather noticeable background. The intensity of the radiation due to the stopping of the electrons was measured with a Geiger counter of semicylindrical shape, the plane wall of which

was close to the paraffin block (diameter of the counter 40 mm, length of the working part 80 mm). In this way it became possible to utilize the maximum solid angle of the radiation arising in the target. The background due to the paraffin absorber was subtracted in each measurement.

We investigated: 1) the variation in the intensity of the radiation with the atomic number for two initial energies (1 and 2 MV), 2) the variation in the intensity of the radiation with the initial energy of the electrons, and 3) the dependence of intensity on the thickness of the target (transition from a thin target to a thick one).

The variation in the intensity of radiation with the atomic number was examined for an initial energy of 1 MV, the thicknesses of the targets (Pb, Sn, Cu and Al) being 15, 22, 33 and 54 mg/cm² respectively; for an initial energy of 2 MV the targets used were twice as thick. The effective cross-sections obtained are given in Table 1.

Table 1

Element	σ/Z^2	
	$E=1$ MV	$E=2$ MV
Al	1.06	0.86
Cu	0.93	0.92
Sn	0.87	—
Pb	1.00	1.00

In the above, σ denotes the effective cross-section of the radiative stopping (in arbitrary units), Z being the atomic number of the element. The statistical accuracy in determining σ amounts to 10% of the value obtained. In calculating the effective cross-section, allowance was made for the difference in the background obtained with the various targets; indeed, since the electrons enter into the absorber after having lost part of their energy in the target, the radiative background decreases to a greater or lesser extent depending on the given target. It can easily be shown that the correction to be introduced consists in diminishing the experimental figure by the amount $\frac{Z}{Z - Z_1 \frac{\Delta}{\Delta_1}}$, where Z_1 is the atomic number of the absorber, Δ and Δ_1 being the energy losses through ionization referred to 1 electron per cm², in the substance examined and in the absorber, respectively. In our experiments the correction proved comparatively small, except in the case of aluminium. Table 1 shows the ratio σ/Z^2 to be constant, in accord with the theory; the fluctuations do not exceed the limits of experimental error.

The variation of the effective cross-section with the initial energy was also found to be in fairly good agreement with the theory. The ratio of the intensity of the radiation for $E=2$ MV to that corresponding to $E=1$ MV was 1.95 in the case of aluminium, and 2.3 in the case of lead (referred to 1 incident electron and 1 nucleus), the error in both cases being about 10%. The theoretical value, according to Bethe and Heitler [2], is 2.05 in both cases. The thinnest targets were used for these measurements.

When examining the variation of the intensity of the radiation with the thickness of the target, the optimum depth could be determined, at which the intensity of the radiation attains its maximum value and then decreases owing to absorption. The knowledge of this depth is of considerable practical interest for the experimental study of fast electrons; corresponding figures are given in Table 2.

Table 2

Element	Initial energy	x_m, mg/cm²
Pb	1 MV	227
Cu	1 »	310
Cu	2 »	620

As might be expected, the value of x_m increases with the increase of the initial energy and decreases with the increase of Z (due to scattering).

A comparison of the intensity of the radiation for thin and thick targets showed also a good agreement between theory and experiment. It follows that the so-called anomalous energy losses reported by several authors[3] for the fast electrons constitute but a small fraction of the total losses of electron energy in matter.

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Received
26.X.1939.

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Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1939. Volume XXV, № 8

PHYSICS

ON THE ASYMMETRY OF THE EFFECTIVE CROSS-SECTION FOR COLLISIONS OF THE SECOND KIND

By V. L. GINSBURG

(Communicated by L. I. Mandelstam, Member of the Academy, 17. X. 1939)

In considering collisions of the second kind one feature of this process is, to the best of our knowledge, usually overlooked. Let us begin with the case of an electron impact with an atom which for the sake of simplicity we will assume to possess one optical electron without spin. The differential effective cross-section for a collision of the second kind (the atom performs the transition $N \to 0$, the electron suffers a change of momentum $\vec{q} = \vec{p}_0 - \vec{p}_1$, where $\vec{p}_0$ is the initial momentum) for the case when the first Born approximation is applicable, is (1)

$$d\Phi_{N\to 0}(\vec{q}) = \frac{4e^4m^2}{\vec{q}^4} \frac{|\vec{p}_1|}{|\vec{p}_0|} \left| \int U_0^*(\vec{r})\, U_N(\vec{r})\, l^{\frac{i\vec{q}\vec{r}}{\hbar}}\, d\tau \right|^2 d\Omega \qquad (1)$$

where U_0 and U_N are the eigenfunctions of the final and initial (excited) states. The above peculiarity consists in the fact that $d\Phi_{N\to 0}$ depends essentially on the manner in which the atom has been excited.

Let us assume to be explicit, that the excited state is *np*, the initial state (before excitation) and the final one (after a collision of the second kind) being $1S$ states. Then, when the atom is excited by light, that one of the three possible *np* states with various m is excited, for which the projection of the moment of momentum on the direction of the electric light vector $\vec{E}$ is zero. The state *np* is degenerate with respect to the magnetic quantum number m; therefore the choice of a system of eigenfunctions (with various m) belonging to the term *np* is arbitrary (2). Let us choose these functions in a system with the polar axis directed along $\vec{q}$. Then if $\vec{E} \parallel \vec{q}$, there is a given probability that there will be excited the state having the function *

$$U_{N_{||}} = R_{n_1}(r)\, \frac{P_{10}(\cos\vartheta)}{\sqrt{2\pi}}. \qquad (2)$$

* The wave function of an atom excited by light is proportional to the expression (n and l are assumed given) $\psi_{nl} \sim \sum_m \left(\int U_{100} \vec{E}\vec{r}\, U_{nlm}\, d\tau \right) U_{nlm}$.

If, on the other hand, $\vec{E} \perp \vec{q}$, then U_N is equal to

$$U_{N\perp} = \frac{R_{n_1}(r)}{\sqrt{4\pi}} P_{11}(\cos\theta)(e^{i\varphi} - e^{-i\varphi}) \qquad (3)$$

(the OX-axis is taken along $\vec{E}$).

From (1) it is easy to see that in the given case $d\Phi_{N\to 0}$ vanishes for $\vec{q} \perp \vec{E}$ and is different from zero for $\vec{q} \parallel \vec{E}$. Thus, the cross-section for collisions of the second kind is asymmetrical in the sense that it depends on the mutual orientation of the vectors $\vec{q}$ and $\vec{E}$. In the case of very fast electrons for most of the impacts $\vec{q} \perp \vec{p}_0$, and the total cross-section is consequently sharply asymmetrical, too. In general, if relation (1) is valid, asymmetry with respect to the direction $\vec{p}_0$ is

$$A_{p_0} = \frac{\Phi_{\parallel} - \Phi_{\perp}}{\Phi_{\parallel} + \Phi_{\perp}} = \frac{A_q(3\overline{\cos^2\varphi} - 1)}{2 - A_q(1 - \overline{\cos^2\varphi})} \qquad (4)$$

where $A_q = \frac{f_{\parallel} - f_{\perp}}{f_{\parallel} + f_{\perp}}$ denotes asymmetry with respect to the $\vec{q}$ direction, and $\overline{\cos^2\varphi}$ is the mean square of the cosine of the angle between $\vec{q}$ and $\vec{p}_0$ taken over all the collisions. $\Phi_{\parallel}$ and $\Phi_{\perp}$ are the cross-sections for $\vec{E} \parallel \vec{p}_0$ and $\vec{E} \perp \vec{p}_0$ respectively, $f_{\parallel}$ and $f_{\perp}$ — the cross-sections for $\vec{E} \parallel \vec{q}$ and $\vec{E} \perp \vec{q}$.

Expression (1) is correct even in Born's approximation only in case the effect of electron exchange can be neglected. A consideration of exchange, absolutely necessary when dealing with transitions between terms of different multiplicity, also brings us to asymmetry of cross-section for collisions of the second kind, since the excitation probability of states with given n and l but with different m does not remain the same * (1).

The probability of a collision of the second kind increases with a decrease in the velocity of the electrons. For slow electrons Born's approximation is invalid, nor are there any calculations suitable for evaluating A_{p_0} (or A_q) (confer below). It is therefore important to establish the connexion between the asymmetry of cross-section for collisions of the second kind with the experimentally observed polarization of radiation, excited by electron impact. This phenomenon is accounted for by the unequal excitation probability of states with various m in a collision of the first kind. For instance, if expression (1) is valid, then in a co-ordinate system with the polar axis pointing along $\vec{q}$ (2), when excitation takes place, $\Delta m = 0$. If we know only the polarization of the radiation excited by the impact, we cannot yet determine the magnitude of asymmetry of the cross-section, since polarization is measured with respect to the direction of the initial momentum of the incident electron $\vec{p}_1$, whereas the cross-section is determined with re-

* In our opinion it is scarcely correct to call asymmetry of cross-section for collisions of the second kind a peculiarity of the process. As a matter of fact, the probability of a collision of the second kind, as that of other processes, depends on the wave function of the initial state of the given process. At the same time, however, it is essential which one of the possible states with given energy (but with different m) is present.

spect to $\vec{p}_0$ — the direction of the electron, to which energy is transmitted. However, from the fact that polarization of radiation is considerable ([1], [3]) when excitation is due to slow electrons with energies several volts above the excitation potential, it follows that the excitation probability of states with various m in this case also varies materially. For slow electrons we may therefore expect marked asymmetry of cross-section for collisions of the second kind.

If, for simplicity, we assume that the polarization of radiation with respect to the $\vec{q}$ or $\vec{p}_1$ directions is independent of $\vec{q}$ [the former is true in case (1) is valid], then for the determination of A_{p_0} it is sufficient to know the polarization of radiation with respect to the $\vec{p}_1$ direction*.

Such an estimation of asymmetry of the cross-section for collisions of the second kind with an Hg atom in the state $2\,^3P_1$ gives for A_{p_0} values running from—8 to—20% for an energy of the electrons equal to 1.8 eV [the polarization of the line $\lambda = 2537$ Å ($2\,^3P_1 \rightarrow 1\,^1S_0$) for $E = 6.7$ eV $= E_{exc} + 1.8$ eV is—30% ([3])].

One may attempt to detect the asymmetry of cross-section for collisions of the second kind with an apparatus of the type used by Latyshev and Leipunski ([5]). These authors observed collisions of electrons with Hg atoms in the state $2\,^3P_0$. For this state the asymmetry of cross-section is zero, since it is degenerate. But the concentration of the Hg atoms on the level $2\,^3P_1$ cannot be made as great as in the metastable state $2\,^3P_0$. This circumstance in conjunction with the necessity of measuring the effect within a few percent, complicates experimenting. It is also possible to detect collisions of the second kind of electrons with atoms, for instance Hg, by the excitation of the atoms of a non-quenching admixture to mercury vapour. Of course, the admixture must be chosen so, that its excitation potential is less than the sum of the initial energy E of the electron and excitation potential E_{exc} of Hg, but at the same time is greater than E. The use of such a method excludes the complicating effect of photocurrents, present in the apparatus of Latyshev and Leipunski.

A study of the polarization of radiation excited by electron impact shows ([1], [3], [6]) that Born's approximation in the case of sufficiently slow electrons brings us to conclusions which are at sharp qualitative variance with experiment. Thus, according to Born's theory, the absolute value of polarization should be a maximum for $E = E_{exc}$. Experiment, however, shows that for $E = E_{exc}$, $\Pi = 0$; polarization reaches a maximum for an energy several volts above excitation potential, after which it declines. In order to explain this dependence of polarization on energy and to describe for the case of slow electrons all questions pertaining to the polarization of radiation in collisions of the first kind and to asymmetry of cross-section for collisions of the second kind, it is necessary to apply approximations of the theory of collisions, more exact than Born's method. The method of distorted waves and the London-Stückelberg method in use in this field take into consideration only two states: the initial one and one excited state. However, in order to

* At the same time it is also necessary to know the angular distribution of the inelastically scattered electrons. The distribution for slow electrons is in agreement with the predictions of Born's theory([5]). In the following estimation of A_{p_0} for mercury, since it is certain not to be exact, we have made use of the angular distribution calculated by Born's method and corresponding to scattering in hydrogen due to excitation of the $2p$ level; the ratio $\frac{E_{exc}}{E}$ has the same value as in the example for Hg.

explain the phenomena under discussion here, it is absolutely necessary to consider simultaneously all the states of the given term with various m. If we neglect exchange, our initial equations take the following form

$$\left.\begin{aligned} &(\nabla^2 + K_{10}^2) F_{100} = \frac{2m}{\hbar^2} V_{100,\,100} F_{100} \\ &(\nabla^2 + K_{nl}^2) F_{nlm} = \frac{2m}{\hbar^2} \left(V_{100,\,nlm} F_{100} + \sum_{\nu=-l}^{\nu=+l} V_{nl\nu,\,nlm} F_{nl\nu}\right) \\ &m = -l, \quad -l+1, \ldots, 0, \ldots, l-1, \; l \end{aligned}\right\} \qquad (5)$$

The notation here, except for several obvious changes, corresponds to that accepted by Mott and Massey (7).

A solution of the simultaneous equations (5) is hardly possible without essential simplification; however, we see at once the relationship between states with various m that are in strict resonance. If on the right hand side of (5) we substitute Born's values for F, than (5) can be integrated by a quadrature. From this solution we see at once that the exclusion principle $\Delta m = 0$ (confer above) is no longer valid here, and therefore states with all values of m are excited, which should result in a falling off of the polarization of radiation. Similarly to Mohr and Massey's interpretation (8) of the increase in elastic scattering for slow electrons as due to «double» «hyperelastic» collisions, one can attempt to explain the decrease in polarization for small velocities as the result of «double» depolarizing collisions. From this point of view when an electron impinges against an atom, it first of all excites a state permitted by the first Born approximation; then, since in such a collision the electron loses almost all of its energy, it remains near the atom for a comparatively long time and strikes it again, transferring it into a state with a different value of m. The probability of a «double» blow should increase as E approaches E_{exc}, and therefore polarization should decrease as E declines, which is exactly what is observed experimentally in the region up to maximum polarization. The hypothesis formulated above can to a certain extent be checked experimentally, if we measure the polarization of radiation excited in the presence of a strong magnetic field (3) which destroys degeneracy with respect to m. In virtue of this latter reason the probability of a depolarizing impact should decrease, and therefore the maximum of polarization should shift toward lesser values.

The cross-section for collisions of the second kind between atoms is also asymmetrical. In Born's approximation the magnitude of asymmetry is considerable and can be easily computed. However, for the velocities of heavy particles that are encountered this approximation itself is inapplicable, indeed. Only for particles of gas-kinetic velocity have methods been worked out, suitable for determining A_{p_0}. For this case Vlasov and Fursov (9) in a work on the calculation of the width of spectral lines have shown that the probability of the transmission of excitation energy between like atoms depends on the mutual orientation of the vector $\vec{E}$ and on the relative velocities of the atoms, and therefore the cross-section for this process is asymmetrical*.

If for velocities $\sim 10^7$ cm/sec. asymmetry of cross-section is considerable. one can try to detect it in the experiment with an atomic beam. In letting an atomic ray excited by light through the gas, one observes the quenching of fluorescence in connexion with the orientation of the vectors $\vec{E}$ and $\vec{p_0}$ by

* The field must be of course directed so that it does not entirely depolarize the radiation (2).

the drop of the intensity of radiation along the beam or by the width of the radiation line. In the latter case asymmetry of radiation will also appear when the atoms in the beam are excited by unpolarized light. Indeed, the quenching of states with given n and l, but different m is not the same (if the cross-section is asymmetrical), and therefore the width of the line should depend on its polarization, i. e. it should depend on the position of the polarizer through which the radiation is passed before reaching the interferometer.

If Vlasov and Fursov's expression for the width of the line is valid for velocities $\sim 10^7$ cm/sec., then for pressures of several mm of Hg the width of the line for the mercury wave length $\lambda = 2537$ Å should undergo a change of magnitude up to 1 Å with a change in the position of the polarizer. On the contrary, in the case of collisions of the second kind between atoms and electrons there is no hope of attaining electron beams so dense that quenching due to collisions of the second kind could affect the width of the line.

In conclusion, it is a pleasure to thank Prof. G. S. Landsberg for his valuable suggestions during the preparation of the present paper.

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Received
21.X.1939.

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Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1939. Volume XXV, № 8

PHYSICS

STUDIES ON THE POSITIVE COLUMN IN POTASSIUM VAPOUR

By B. KLARFELD

(Communicated by S. I. Wawilow, Member of the Academy, 27. X. 1939)

The suitability of the existing theories of the positive column were checked up to the present time mainly for mercury discharge ([1]—[5]). There were various reasons to chose the mercury vapour, as, for example, the ease with which pure discharge conditions could be produced, the convenient control of the mercury vapour pressure, the insignificant value of secondary electron emission from probes under the effect of metastable mercury atoms, etc. In a previous paper ([5]) we had shown that the theory by Langmuir and Tonks([2]) of low pressure plasma gives a description of the phenomena in mercury discharge which is quantitatively correct, as long as the pressure does not attain a certain value. In developing this theory it was assumed, as it is known, that the positive ions, in moving from the place of their generation to the column walls, suffer no impacts with the gas molecules, i. e., that the pressure is sufficiently low. For a reliable application of this theory to any monoatomic gas it is desirable to check the theory for the case of discharge in some other kind of gas or metal vapour, differing from mercury vapour by the magnitudes of its atomic constants. As such a substance we have chosen potassium, since it possesses a saturated vapour pressure suitable for these discharge investigations and an ionization potential about $2\frac{1}{2}$ times lower than that of mercury; furthermore there are no metastable states in a potassium atom, and therefore measurements of ion-current densities can be carried out without impediment from this side. A description of the investigations of potassium discharge is given below.

A discharge tube with 32 mm diameter was used (Fig. 1) containing a current-heated tungsten cathode k, anode a, a first flat probe S_2, and axial cylindrical probes S_1 and S_3. The pressure of vapour of the potassium located in the side-tube P was determined from the temperature of the massive red copper cup F. The temperature of this cup could be easily and quickly adjusted to the desirable magnitude by means both of the helical heater and of the flow of cooling air passing through a circular channel in the body of the cup. The side-tube P was located about midway between probes S_1 and S_3, in order to reduce the effect of the longitudinal variation of the vapour pressure on the probe measurements ([6]).

The random electron current densities and thus the electron concentrations were determined as previously by the bend of the semilogarithmic characteristics of the electron current. The characteristics $i^2{}_s = f(V_s)$ (which should be straight lines for thin cylindrical probes under accelerating

fields) were not employed in determining the electron concentrations for the following reasons. The theory of probe currents with fields accelerating the charged particles for probes of spherical and cylindrical form had been developed by Langmuir and Mott-Smith; it was assumed by them that all the charged particles arriving at the probe surface will be collected by the latter (immediately or after an inelastic reflection). However, a number of investigations ([7],[8],[9]) have shown that an appreciable part of the electrons are elastically reflected from the metal surfaces, and thus cannot be collected by the probes. Part of the inelastically reflected electrons that had sufficient velocity before entering the layer around the probes, overcome after reflection the retarding field and are removed from the probes. Since the general reflection coefficient, as well as the relation between the number of elastically and inelastically reflected electrons greatly depend on the electron velocities and on the condition of the metal surface, the *determination of the electron concentrations and space potentials from the treatment of the characteristics* $i^2_s = f(V_s)$, *may result in serious errors.* The experimental data available in literature also confirm this conclusion.

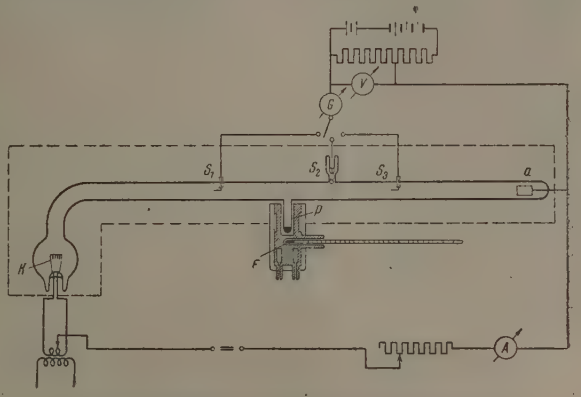

Fig. 1. Discharge tube for the measurements.

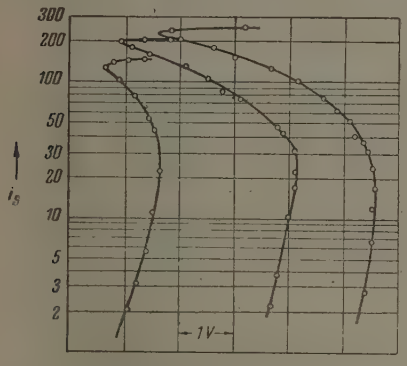

Fig. 2. Form of distortion of probe characteristics of electron current.

Considerable distortions frequently observed in the semilogarithmic characteristics of electron current should be noted as a peculiarity of probe measuremens in potassium vapour. An example of these characteristics is shown in Fig. 2. This distortion appears only when the pressure of potassium vapour reaches 10^{-3}—10^{-2} mm, and is expressed more distinctly with larger probe dimensions and greater probe-to-anode spacings. This phenomenon is due to that with greater probe currents and a constant value of discharge current indicated by ampermeter A (Fig. 1), the magnitude of the current in the probe-to-anode section falls considerably, displacing the equipotential surfaces along the column towards the anode (as a result of the falling characteristics of potential-gradient in the column versus-current). At the same time the distortion of the characteristics noted in Fig. 2 takes place, which is a displacement of the space potential to the left. The occurrence of such strong distortion just in potassium discharge is facilitated by the falling character of the potential-gradient versus-current characteristics which is especially strongly expressed for alkaline metals (when the vapour pressure

is sufficiently high). The increasing distortion with increasing anode-to-probe spacing is due to the accompanying increasing displacement of the equipotential surfaces.

The distortion of the probe characteristics described above may occur to some or othes degree in discharges in other gases. This may possibly account for a part of observations made by some authors on the semilogarithmic electron current characteristics deviating from the straight line.

The theory of the low pressure plasma establishes a quantitative relation between the following quantities: 1) between the density of the ion current to the insulated wall, I_p, and the electron concentration, n_m, along the column axis; 2) between the electron concentration along the column axis and their concentration, n_w, at the walls; 3) between the ratio of the random and directed electron currents B and the ratio I_p/ι, where i is the discharge current in the positive column; 4) between the number of pairs of ions generated per plasma electron per second and the electron temperature. The validity of these relations in potassium discharge was checked in the same way as recently described for mercury discharge ([5]). The results are summarized in the following table.

Discharge Current 1 Amp; Column Diameter 32 mm

Temper. of side-tube T, °C	Pressure of potassium vapour reduced to 0°C, mm Hg	Electron temper. °K	I_p exper., mA/cm²	I_p calc. mA/cm²	n_m/n_w	B_{exp}	B_{cal}	α_{exp}	α_{calc}
1	2	3	4	5	6	7	8	9	10
137	0.00012	12750	0.56	0.43	1.76	0.79	0.85	126.10^3	113.10^3
146	0.00023	8900	0.60	0.56	1.75	0.96	0.92	91	95
177	0.0012	5450	0.54	0.86	2.3	1.36	0.79	44	74
187	0.002	4000	0.54	1.60	3.6	2.4	0.84	23	63

It may be seen from the table that *the agreement between the data experimentally obtained and calculated by the theory of Langmuir and Tonks is very satisfactory at pressures up to* $p_0=0.001$ mm. The discrepancies occurring at higher pressures increase rapidly and show the tendency predicted by theoretical considerations. The investigation of these discrepancies made with various discharge currents has shown that, like in the case of mercury discharge. *the principal cause of the discrepancies lies in the collisions of the positive ions with the potassium atoms occurring with the ions moving to the walls.* This is expressed particularly by the fact that the limiting pressure for the validity of the low pressure plasma theory for potassium discharge is by one order of magnitude lower than for mercury discharge plasma. An approximately similar relation exists between the mean free paths of charged particles in potassium and mercury vapour.

As columns 4 and 5 of the table show, the relation between I_p and n_m predicted by the low pressure plasma theory starts to deviate from the expe-

rimental values already at the pressure of $2 \cdot 10^{-3}$ mm Hg. However, this relation was employed by Mohler ([10]) for caesium discharge (which in respect of its properties is very close to the potassium discharge) up to pressures of 0.3 mm. The value of the electron concentration along the discharge axis determined by Mohler from the experimental value of I_p, must be at least by one or two orders of magnitude lower than the actual values.

In column 6 of the table is given the ratio of the electron concentrations at the column axis and at the walls. At low pressures this ratio is constant, as it should be according to the low pressure plasma theory, and it rapidly increases with pressure. From the value of n_m/n_w at low pressures the non-dimensional constant η_0 of the plasma theory may be determined; it is equal to $-eV_0/kT_e$ where V_0 is the potential difference between the axis of the column and the boundaries of the plasma layer. Similarly to the case of mercury discharge ([5]), η_0 is about one half of what is required by the theory. This discrepancy is due to the fact that at the boundaries of the plasma and the layer the derivative $\partial V/\partial r$ is not at all minus infinity, as it is approximately assumed by the theory. The ratio of the densities of the random electron and ion currents at the walls may be calculated from the value of η_0 determined experimentally. From the Boltzmann relation and uniformity of T_e across the cross-section of the column it follows that the ratio of the random electron current density at the axis I_{em} to its density at the walls I_{ew}:

$$\frac{I_{em}}{I_{ew}} = \varepsilon^{\eta_0}.$$

The theory of the low pressure plasma yields

$$I_p = 2s_0 h_0 \left(\frac{m_e}{\pi m_p}\right)^{1/2} I_{em};$$ *

therefore

$$\frac{I_{ew}}{I_p} = \left(\frac{m_p}{\pi m_e}\right)^{1/2} \frac{1}{2s_0 h_0 \varepsilon^{\eta_0}}.$$

In substituting for η_0 its value 0.6 found for mercury and potassium, we obtain for I_{ew}/I_p values that agree very well with the experimental data (for mercury $I_{ew}/I_p \approx 350$, for potassium ≈ 160). Thus, the value of the ratio I_{we}/I_p obtained experimentally can be satisfactorily explained by Langmuir-Tonks theory without any additional hypotheses as to the character of velocity distribution of the positive ions.

The experimental and calculated values of α (see columns 9 and 10 of the table) agree fairly well with each other at low pressures. Roughly approximate calculations of the effective cross-section, Q_i, for ionization of potassium atoms from the value of α show that this cross-section exceeds several tens of times the value found for potassium by Funk ([11]). By applying the method of crossed atom and electron beams Funk had determined Q_i and found it equal to 11 cm^2/cm^3 at the maximum of the ionization function. This result is however rather surprising, since such a value of Q_i makes up only about 1% of the entire effective cross-section of potassium for all kind of collisions, while for mercury under corresponding conditions it constitutes more than a half of the entire cross-section. Therefore a repeated experimental determination of Q_i is most desirable.

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* For the low pressure cylindrical plasma s_0 is 0.7722 and h_0 is 0.35. Since the derivative $\partial U/\partial r$ at the plasma layer boundaries is not minus infinity, it follows that the value of s_0 decreases and h_0 increases, their product remaining practically constant.

In our previous paper ([5]) we made the suggestion that for the discharge in alkaline metal vapour N_e/i, the value of the ratio of the number of electrons per 1 cm of column length to the discharge current will change greatly with the current. In Fig. 3 this ratio is given for potassium discharge. As seen from the curves an eight-fold increase of discharge current at pressure $p_0 = 0.002$ mm actually results in a four-fold increase of N_e/i. In other words, *in vapour of alkaline metals, except for very low pressures, no proportionality between electron concentration and accuracy can be assumed, even at the first approximation.*

A determination of the electron mean free path, λ_e, in potassium discharge has shown (as previously found for discharges in Ar, He and Hg vapour) that λ_e determined by the method of Killian* is very close to the results obtained by direct measurements, and is equal to $1 - 1.5 \cdot 10^3$ cm^2/cm^3 at $p_0 = 1$ mm Hg. It was found that λ_e decreases appreciably with increase in the discharge current. The calculation of the effective cross-section of positive ions according to the value of decrease of λ_e with the current ([12], [13]), will be very inaccurate in the case of potassium, the increase in current causing an appreciable fall in T_e, and, accordingly, there will be a change not only in the concentration of the potassium positive ions, but also in the value of their effective cross-section and in the value of the effective cross-section of the normal atoms. All these circumstances make the calculations of the effective cross-section of positive ions scarcely advisable for the case discussed above.

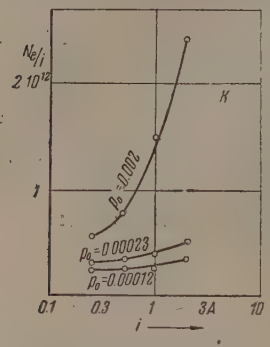

Fig. 3. Ratio N_e/i as function of current.

In concluding it should be emphasized that the good agreement between the equations of the plasma theory by Langmuir and Tonks for discharges in mercury and potassium vapour and the results of their check by the probe method, thus confirms the validity of the low pressure plasma theory. It points at the same time to the fact that the probe method is quite applicable for quantitative investigations of discharges.

J. P. Djalostib participated in the experimental part of this work.

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Received
14.X.1939.

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* In this case $1/\lambda_e$ is equal to the effective cross-section for the transfer of momentum

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PHYSICS

ON THE PROBABILITY OF EXCITATION OF A POTASSIUM ATOM

By V. FABRIKANT

(Communicated by S. I. Wawilow, Member of the Academy, 20. X. 1939)

The mechanism of excitation of radiation in low pressure discharges is distinguished by its simplicity. The atoms are excited by electron impacts and then yield their energy in the form of radiation. With sufficiently low currents and pressures there is no appreciable quenching of the radiation, and therefore the number of emission acts is simply equal to that of excitation acts. Under these conditions the «capture» of the radiation, as we have previously emphasized (1), does not affect the absolute value of the flux of radiation emitted by the discharge. With these simple considerations serving as a basis, we succeeded in calculating the absolute intensity of radiation for sodium (1) and mercury (2) discharges. The agreement of these calculations with experimental data testified to the quantitative correctness of the accepted conceptions.

The probability of the respective atom being excited by an electron impact, that is the effective cross-section of the atom for an exciting collision with an electron, served as the principal atomic constant in these calculations. We made use of the data on excitation probabilities determined in experiments with electron beams. However, such data are available only for a very few atoms. Therefore it is of interest to solve the problem inversely—to determine the probability of excitation from the data on the intensity of discharge radiation.

This procedure is, of course, less accurate than the direct determination of excitation probability, but for certain cases it may yield rather reliable results. In particular such a possibility is offered by the data on potassium discharge published by B. Klarfeld (3). At the same time there are no reliable data on the probability of excitation for the potassium atom. This magnitude had been determined by Williamson (4) alone; his method, however, met criticism on the part of Funk (5), who altogether renounced to the determination of the probability of excitation, confining himself to the probability of ionization.

To determine the excitation probability or the effective cross-section of the potassium atom, we shall make use of a relation obtained in one of the previous papers (1) [see formula (5)]. This relation connects the number of exciting collisions with vapour density, electron concentration, electron temperature and the effective cross-section of the atom. Besides this, it essentially involves the excitation potential and the parameter determining the form of the excitation function. Vapour density, electron concentration and electron temperature are given in the paper by B. Klarfeld (3). Moreover, the above paper contains data on the power expenditure per unit

length of discharge column and on the power transported by the ions onto the discharge walls. With sufficiently low pressures and currents the difference of the values of both powers may simply be taken equal to the power converted into radiation of potassium resonance lines 7645 and 7694 Å.

The relations observed in the case of low pressure sodium and mercury discharges should convince one of the validity of this assumption. By dividing the energy of radiation by the magnitude of a quantum equal to $2.55 \times \times 10^{-12}$ erg, we obtain the number of emission acts which is equal to the number of radiation acts. Now there remains unknown, besides the sought for effective cross-section, only the form of the excitation function. The parameter characteristic of this unknown form is equal to the difference between the potential corresponding to the maximum of the excitation function (V_m) and the excitation potential (V_a). We assume this difference equal to 5 Volts, similar to that for sodium. Owing to the similarity of both atoms, such an assumption seems to be quite valid, although the calculations become, of course, somewhat arbitrary.

Thus, all of the quantities, except the effective cross-section, can be considered as known, and the relation for the number of excitation collisions permits to determine the effective cross-section. The calculation results for various discharge conditions are presented in the table.

Pressure in mm Hg	Current in Amp.	Power of radiation in Watts	Effective cross-section in $cm^2 \times 10^{14}$
1.2×10^{-4}	0.5	0.065	2.3
	1.0	0.12	1.9
2.3×10^{-4}	0.5	0.093	2.1
	1.0	0.16	1.9
1.2×10^{-3}	1.0	0.25	1.9
Average value	—	—	2.0

These values of the effective cross-section correspond to the crest of the excitation function $Q(V_m)$. It is seen that within the given range of pressures the maximum effective cross-section does practically not depend on pressure, i. e. it is actually an atomic constant. The discharge conditions chosen here correspond to the most reliable probe measurements.

To the average value of $Q(V_m)$ obtained there corresponds a cross-section of potassium atom, reduced to 1 mm Hg 0° C, equal to 720 cm^2/cm^3 (for excitation). According to the measurements of Brode [6], the complete effective cross-section of potassium atom is equal to 800 cm^2/cm^3 (for electrons with energy of 7 Volts). It is seen that the value obtained by us does not contradict the data by Brode. Their results are hardly worth comparison on account of the little accuracy in their determination.

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Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
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MATHEMATISCHE PHYSIK

ZUR BEUGUNG AN EINEM SPALT, RESP. STREIFEN. II

Von W. S. IGNATOVSKIJ (W. IGNATOWSKY), korrespondierendem Mitglied der Akademie

Wir betrachten jetzt den Streifen, wobei wir Fall I berücksichtigen. Es wird für uns notwendig sein $N_0(y)$, welche Grösse ja überall auf der YZ-Ebene stetig sein wird und dort für $|y| \leqslant a$ verschwindet, nur für $y \geqslant a$ zu berechnen, weshalb wir aus (6) (1) wegen (4) (1) der vorhergehenden Arbeit, erhalten:

$$C(y) = \frac{1}{\pi}\int_a^\infty N_0(s)\,Q_0[\varkappa(s+y)]\,ds + \frac{1}{\pi}\int_a^\infty N_0(s)\,Q_0[\varkappa(s-y)]\,ds;\ 0 \leqslant y \leqslant a. \quad (1)$$

Weiter ergibt uns (2) (1), bei $x=0$, unter Berücksichtigung, dass laut unserem Satze $H_0(y) = -i\varkappa$ für $y \geqslant a$ sein wird,

$$N_0(y) = \frac{1}{\pi}\int_{-a}^{+a} H_0(s)\,Q_0[\varkappa(s+y)]\,ds - \frac{i\varkappa}{\pi}\int_a^\infty Q_0[\varkappa(s+y)]\,ds -$$

$$-\frac{i\varkappa}{\pi}\int_a^y Q_0[\varkappa(y-s)]\,ds - \frac{i\varkappa}{\pi}\int_y^\infty Q_0[\varkappa(s-y)]\,ds;\ y \geqslant a. \quad (2)$$

Fassen wir nun die drei letzten Integrale zusammen und beachten (13) unserer vorhergehenden Arbeit, so folgt

$$N_0(y) = 1 + \frac{i\varkappa}{\pi}\int_{y-a}^{y+a} Q_0(\varkappa s)\,ds + \frac{1}{\pi}\int_{-a}^{+a} H_0(s)\,Q_0[\varkappa(s+y)]\,ds;\ y \geqslant a. \quad (3)$$

Setzen wir nun in (5) (1) den Ausdruck (1) ein und berücksichtigen die Differentialgleichung für $Q_0(x)$, so erhalten wir

$$H_0(y) = -\frac{\varkappa}{\pi}\int_a^\infty \frac{N_0(s)\,Q_0[\varkappa(s+y)]}{s+y}\,ds - \frac{\varkappa}{\pi}\int_a^\infty \frac{N_0(s)\,Q_0[\varkappa(s-y)]}{s-y}\,ds;\ |y| < a. \quad (4)$$

Mit diesem Wert von $H_0(y)$ gehen wir nun in (3) ein und beachten dabei, dass $N_0(y)$ bei $y \to \infty$ in den Wert der einfallenden Welle übergehen muss. Wir erhalten dann, wobei die Berechtigung der Vertauschung der Integrationsfolge begründet werden kann,

$$N_0(y) = 1 + \frac{i\varkappa}{\pi}\int_{y-a}^{y+a} Q_0(\varkappa s)\,ds + \int_a^\infty N_0(t)\,K_3(y,t)\,dt;\ y \geqslant a \quad (5)$$

mit

$$K_3(y,t) = -\frac{\varkappa^2}{\pi^2}\int_{-a}^{+a}\frac{Q_1[\varkappa(t+s)]}{\varkappa(t+s)}\{Q_0[\varkappa(y+s)]+Q_0[\varkappa(y-s)]\}\,ds;\quad y \geqslant a. \tag{6}$$

Was die gesuchte Integralgleichung darstellt.

Endlich kehren wir zu unserem Spalt zurück, und betrachten dabei Fall II.

Hierbei verstehen wir wieder, wie bei der Behandlung des Falles II in unserer vorhergehenden Arbeit, unter $u(x,y)$ die magnetische Kraft, welche demnach parallel der Z-Achse sein wird und überall stetig ist. Wir führen nun die Grösse

$$P_0(y) = 1 - cN_0(y) \tag{7}$$

ein und ersehen, wegen der Bedeutung von $N_0(y)$, welche letztere Grösse innerhalb des Spaltes ja $\frac{1}{c}$ sein wird, dass $P_0(y)$ auch überall längs der YZ-Ebene stetig ist, und für $|y| \to \infty$ der 1 sich nähert, da dabei $N_0(y)$ zu Null strebt. Bei $y = a$ wird augenscheinlich $P_0(a) = 0$.

Wir erhalten demnach, analog den Erörterungen nach (12) bis (17) unserer vorhergehenden Arbeit und laut unserem Satze

$$P_0(y) = 1 + \frac{i\varkappa}{\pi}\int_{y-a}^{y+a} Q_0(\varkappa s)\,ds + \int_a^\infty P_0(t)\,K_3(y,t)\,dt;\quad y \geqslant a \tag{8}$$

mit derselben Bedeutung von $K_3(y,t)$, wie in (6).

Deshalb ergibt sich auch hierbei, wie für den Streifen im Falle I, so auch für den Spalt im Falle II, eine und dieselbe Integralgleichung (5) resp. (8).

Auch jetzt wollen wir nun diese Integralgleichung umformen, zu welchem Zweck wir dort $y = a$ setzen und erhalten dann

$$0 = 1 + \frac{i\varkappa}{\pi}\int_0^{2a} Q_0(\varkappa s)\,ds + \int_a^\infty P_0(t)\,K_3(a,t)\,dt. \tag{9}$$

Subtrahieren wir dies von (8), so ergibt sich

$$P_0(y) = \frac{i\varkappa}{\pi}\int_a^y \{Q_0[\varkappa(s+a)] - Q_0[\varkappa(s-a)]\,ds + \int_a^\infty P_0(t)\,K_4(y,t)\,dt;\quad y \geqslant a \tag{10}$$

mit

$$K_4(y,t) = K_3(y,t) - K_3(a,t). \tag{11}$$

Wir können dies nun weiter umformen, indem wir setzen

$$P_0(y) = \int_a^y R(\eta)\,d\eta;\quad y \geqslant a \tag{12}$$

und erhalten

$$R(y) = \frac{i\varkappa}{\pi}\{Q_0[\varkappa(y+a)] - Q_0[\varkappa(y-a)]\} + \int_a^\infty R(\eta)\,K_5(y,\eta)\,d\eta;\quad y > a \tag{13}$$

mit

$$K_5(y,\eta) = \frac{\varkappa^2}{\pi^2}\int_\eta^\infty dt\int_{-a}^{+a}\frac{Q_1[\varkappa(t+s)]}{t+s}\{Q_1[\varkappa(y+s)] - Q_1[\varkappa(y-s)]\}\,ds;\quad y > a. \tag{14}$$

Weiter kann man nun zwei unbestimmte Integrale ableiten:

$$\int \frac{Q_1(\alpha+z)}{\alpha+z} Q_0(\beta+z)\,dz = \frac{\beta+z}{\alpha-\beta}\{Q_1(\alpha+z)\,Q_0(\beta+z) - Q_0(\alpha+z)\,Q_1(\beta+z)\} \quad (15)$$

und

$$\int \frac{Q_1(\alpha+z)}{\alpha+z} Q_0(\beta-z)\,dz = \frac{z-\beta}{\beta+\alpha}\{Q_1(\alpha+z)\,Q_0(\beta-z) + Q_0(\alpha+z)\,Q_1(\beta-z)\} \quad (16)$$

wobei die Argumente von $Q_0(x)$ resp. $Q_1(x)$ reell und gleich, oder grösser als Null angenommen sind. Durch unmittelbare Differentiation lässt sich die Richtigkeit von (15) und (16) beweisen.

Ebenfalls, wie in der vorhergehenden Arbeit, ersehen wir auch hier, dass alle Kerne unsymmetrisch in Bezug auf ihre Argumente sein werden.

Zu gleicher Zeit folgt aus (15) und (16), dass in dem offenen Intervall $(-a, a)$, resp. (a, ∞), die entsprechenden Kerne stetig und endlich sind, auch in dem Falle, dass die beiden Argumente einander gleich sein werden. Tritt dass letztere ein und sind beide gleich a, so muss man hierbei beachten, dass $N_0(a) = 0$ sein muss, so, dass die entsprechenden Integrale endlich bleiben.

Hierbei muss man berücksichtigen, dass die Kerne unendlich werden, wie z. B. $\frac{\lg(a-y)}{a-y}$ bei $y \to a$.

Was (23) und (24) der vorhergehenden Arbeit anbelangt, resp. (13) und (14), so wird dabei nur das offene Intervall $|y| < a$, resp. $y > a$, angegeben.

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Eingegangen
d. 10.X.1939.

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1939. Volume XXV, № 8

BIOPHYSICS

ONCE MORE ON THE RECORDING OF THE MOVEMENTS OF THE DOLPHIN IN THE SEA

By I. I. STAS

(Communicated by P. P. Lazarev, Member of the Academy, 19. X. 1939)

In the preceding work (1) we were able to prove by means of recording the movements of the dolphin, that the different parts of its body perform oscillations in the horizontal plane, and not only in the vertical one, as some biologists had supposed previously. In other words, we have shown that a wave polarized to a circle or an ellipsis runs along the body of the dolphin—in complete accordance with the theory suggested by Shoulejkin (2).

The apparatus which had been used by us at that time recorded only the horizontal components of the motion, without being in any way affected by the vertical ones. Now, after the main element of the dolphin kinematics had been elucidated experimentally, there arose the question what is the polarization of the wave running along the body of the dolphin: is it polarized to a circle, or to an ellipsis?

To answer this question we have designed an additional device for the principal self-recorder, the mechanism of which was also very simple.

Namely, the end of the string passing along the dolphin's back to the apparatus placed on the «saddle» was fastened to a ring circling the end of the dolphin's tail. Here the string acted upon the slide-block with a point which moved to and fro on the drum of the self-recorder when the tail rose or fell. Consequently, the displacements of this point corresponded to the vertical components of the motion of the end of the tail.

But in the preceding work it has already been pointed out that the drum itself has been turning to the right and left in accordance with the h o r i z o n t a l components of the movement of the tail. As a result a curve reproducing immediately the o r b i t of the end of the dolphin's tail was fixed on the wax layer covering the drum (over thin paper).

This orbit proved to be an e l l i p s i s w i t h t h e r a t i o o f t h e h a l f-a x e s a b o u t 1 : 1.5. The bigger half axis corresponded to the vertical components of the movement and the smaller—to the horizontal ones.

Thus, we have proved that in the dolphin's movements in the sea a wave polarized to an ellipsis not much differing from a circle runs uninterruptedly along its body.

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Received
19.X.1939.

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1939. Volume XXV, № 8

CHEMICAL PHYSICS

RESONANCE THEORY OF AUTOCATALYSIS

By D. A. FRANK-KAMENETZKY

(Communicated by N. N. Semenov, Member of the Academy, 13. X. 1939)

In some cases it may occur that the transition state of a chemical reaction and the reaction product differ only by their electronic structure, having the same nuclear configuration and the same number of unpaired electrons.

Let us denote by A the initial substance (or substances) of the reaction, the transition state—by B^x and the reaction product—by B. The reaction may then be represented as follows:

$$A \rightarrow B^x \rightarrow B. \qquad (1)$$

The energy of activation is equal to the difference between the energy contents of B^x and A.

Let us consider a collision of B with A followed by the above reaction. In this case the transition state will resonate between two canonical structures BB^x and B^xB. This, as well known ([1,2]), results in lowering its energy content by a quantity called «resonance energy». Consequently, the energy of activation of the reaction:

$$A + B \rightarrow [BB^xB^xB] \rightarrow 2B \qquad (2)$$

will be less than the energy of activation of reaction (1).

In the simplest case, when the interaction of B and B^x is due only to resonance, the difference in activation energies will be equal to the resonance energy, which, as known, may be quite considerable.

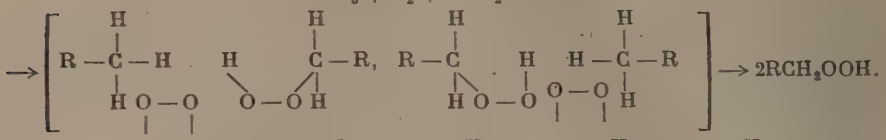
If the energies of the two canonical structures are not exactly equal, the resonance energy will be less. Such, for example, will be the case for a decomposition reaction of the kind:

$$AB + B \rightarrow [A \ldots B^xB, A \ldots BB^x] \rightarrow A + 2B.$$

We arrive thus at a very simple and plausible explanation of some cases of autocatalysis.

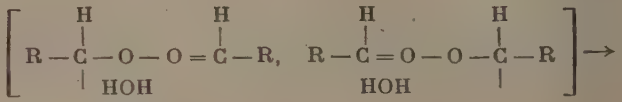
The following examples, taken from the reactions of oxidation of hydrocarbons, may be explained by the proposed mechanism:

$$RCH_3 + O_2 + RCH_2OOH \rightarrow$$



$$\rightarrow 2RCH_2OOH.$$

$$RCH_2OOH + RCHO \rightarrow$$



$$\rightarrow 2RCHO + H_2O.$$

Other explanations are of course also possible.

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Received
13.X.1939.

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Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
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CHEMICAL PHYSICS

PERIODIC PROCESSES IN THE KINETICS OF OXIDATION REACTIONS

By D. A. FRANK-KAMENETZKY

(Communicated by N. N. Semenov, Member of the Academy, 13. X. 1939)

Let us consider an autocatalytic reaction proceeding with the participation of two active intermediate products X and Y, the product X being formed autocatalytically from the initial substance A, and the product Y, also autocatalytically, from the product X.

The reaction scheme can be represented by the following equations:

$$A+X\rightarrow B+2X \qquad \text{(I)}$$
$$X+Y\rightarrow B+2Y \qquad \text{(II)}$$
$$A+Y\rightarrow B \qquad \text{(III)}$$

where A denotes the initial substances and B — the final products of the reaction. The corresponding kinetic equations are:

$$\frac{dx}{dt}=k_1ax-k_2xy \qquad (1)$$
$$\frac{dy}{dt}=k_2xy-k_3ay \qquad (2)$$

where k_1, k_2, k_3 are velocity constants of the reactions (I), (II), (III) respectively, and a, x, y — the concentrations of the substances A, X, Y.

The system of equations (1), (2) shows quite unusual properties: it describes a chemical process proceeding in a periodical way. If the concentration x is less than the «critical» value

$$x_{cr}=\frac{k_3a}{k_2} \qquad (3)$$

then, according to (2), $\frac{dy}{dt}$ is negative and the concentration y diminishes. If x exceeds the critical value, $\frac{dy}{dt}$ is positive and y increases with the time. On the other hand, if y is less than the «critical» value:

$$y_{cr}=\frac{k_1a}{k_2} \qquad (4)$$

then, according to (1), $\frac{dx}{dt}$ is positive and x increases. If y exceeds y_{cr}, $\frac{dx}{dt}$ is negative, and x diminishes with the time.

Let the initial values of x and y be less than x_{cr} and y_{cr}. Then x will increase while y decreases. But y decreases only, until x has reached the critical value. Once this value is reached, the concentration y begins to increase. Arter y has reached its critical value, $\frac{dx}{dt}$ becomes negative and x begins to diminish. When x reaches its critical value again and becomes less than x_{cr}, y begins to decrease, and so on.

In general the process represents a kind of non-linear vibrations, x_{cr} and y_{cr} being the equilibrium positions. If the initial values of x and y differ only slightly from x_{cr} and y_{cr}, i. e. in the case of chemical vibrations of low amplitude, the vibrations become approximately linear.

By introducing the variables

$$\xi = x - x_{cr} \tag{5}$$

$$\eta = y - y_{cr} \tag{6}$$

the equations (1), (2) are brought to the form:

$$\frac{d\xi}{dt} = -k_3 a\eta - k_2 \xi\eta \tag{7}$$

$$\frac{d\eta}{dt} = k_1 a\xi + k_2 \xi\eta. \tag{8}$$

Assuming ξ and η to be small, and neglecting the product of these two small quantities, we obtain:

$$\frac{d\xi}{dt} = -k_3 a\eta \tag{9}$$

$$\frac{d\eta}{dt} = k_1 a\xi \tag{10}$$

$$\frac{d^2\xi}{dt^2} = -k_3 a \frac{d\eta}{dt} = -k_1 k_3 a^2 \xi \tag{11}$$

$$\frac{d^2\eta}{dt^2} = k_1 a \frac{d\xi}{dt} = -k_1 k_3 a^2 \eta. \tag{12}$$

Thus, for low amplitudes, we obtain true harmonic oscillations of the type:

$$\xi = \xi_0 \sin \sqrt{k_1 k_3}\, at \tag{13}$$

$$\eta = -\eta_0 \cos \sqrt{k_1 k_3}\, at. \tag{14}$$

Here it is assumed that at $t = 0$, $x = x_{cr}$, $y < y_{cr}$.

It appears probable that the above-mentioned mechanism may play an important part in the oxidation of higher hydrocarbons, and that it may explain the peculiar phenomena of two-stage ignition (1). In this case the rôle of the product X is played by organic peroxides, the rôle of the product Y—by aldehydes. A cool flame process should have a vibrational character, which seems under certain conditions to be proved by experiment.

A more detailed discussion of the phenomena of the cool-flame oxidation of hydrocarbons from the point of view of the present theory will be published elsewhere. The possibility of vibrational processes in the kinetics of oxidation reactions seems to be of general importance (2–8). Let us add that processes of this kind may be expected to proceed in living organisms. Rhythm is an essential feature of life. The fundamental biological processes are neither mechanical, nor electrical, but chemical. Consequently, besides the well-khown mechanical and electrical rhythms of life, an underlying chemical rhythm may be expected, due to processes of the kind described herein.

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Received
13.X.1939.

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Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1939. Volume XXV, № 8

STRATIGRAPHY

BASHKIRIAN BEDS IN NORTH TIAN-SHAN

By V. A. VAKHRAMEEV and A. D. SMIRNOV

(Communicated by A. D. Arkhangelsky, Member of the Academy, 28. X. 1939)

For the first time the Bashkirian beds were separated out as an independent stratigraphical horizon in 1934 by Semichatova within the territory of Mountainous Bashkiria (2). These beds are characterized by a complex of old coarse costate *Choristites*—*Choristites* ex gr. *bisulcatiformis* Semich. (at present Semichatova is making a monographic study of them) resembling in appearance *Spirifer bisulcatus* Sow., but distinguished by a parallel arrangement of dental plates—a characteristic feature of the subgenus *Choristites*(3). In the sections described by Semichatova the Bashkirian beds are overlain by deposits of the Moscovian stage and are usually separated from the underlying Visean deposits by a series of rocks with a non-characteristic fauna, provisionally referred to the Namurian stage. On the basis of the first appearance of *Choristites*, these guide fossils of the Middle Carboniferous, the Bashkirian beds were referred by Semichatova to the lowermost portion of the Middle Carboniferous deposits. Thus, introducing into the Middle Carboniferous division a new stratigraphical horizon, underlying the Moscovian stage, she has somewhat extended the extent of the Middle Carboniferous which was formerly identified by many with the Moscovian stage.

Subsequent works (3,5) showed the extensive development of the Bashkirian beds in the Urals.

In 1936 V. A. Vakhrameev (1) established the presence of Bashkirian beds within the boundaries of South Ferghana; at the same time he suggested the wide development of this horizon in the north of the Tian-Shan, in the basins of Lakes Son-kul and Issyk-kul.

In 1938, north-eastward from Lake Son-kul, Smirnov discovered in the upper portion of the Carboniferous section, previously referred as a whole to the lower division of this system, an interrelation of limestone, containing coarse costate *Spiriferidae*. Polished sections of their rostral parts permitted to determine them as *Choristites* ex gr. *bisulcatiformis* Semich. This established the Bashkirian age of the enclosing deposits. The section of the Bashkirian beds and of the Lower Carboniferous deposits underlying them is highly variable for the area situated at the latitude of Lake Son-kul, which is accounted for by the transitory character of the Carboniferous deposits of this zone—a zone of pinching out of marine deposits and of a change of their facies in a direction towards the area of the Caledonian land. The beds with *Choristites* ex gr. *bisulcatiformis* Semich. have been met with in two sections.

The former of the two, composed following sai Kumbel (northern slope of the Kok-taï range, north-east of Lake Son-kul), shows the following succession (in ascending order):

1. Dark limestones, abounding in numerous *Gigantella*, lying with an apparent angular unconformity upon the eroded surface of Devonian deposits—10—15 m.

2. A pack of rocks, composed of red uneven-grained sandstones, conglomerates and clay shales—up to 100 m.

3. Sandy limestones, containing *Choristites* ex gr. *bisulcatiformis* Semich.—30 m.

In the second of the two sections, on the northern slope of Mt. Aktash (north of Lake Son-kul) the following rocks are exposed (in ascending order):

1. Grey and dark limestones with intercalations of red and grey arkose sandstones. Thickness 100 m. Locally, the limestones abound in a fauna of the Upper Visean: *Gigantella rectestria* Gröb., *Gig. edelburgensis* Phill., *Productus* (*Striatifera*) *striatus* Fisch., *Pr.* (*Sinuatella*) *sinuata* Kon., *Palaesmilia* cf. *multiplex* Keys., *Lithostrotion* cf. *planocystatum* var. *minor* Vü., *Koninckophyllum* cf. *longiseptum* Pern., *Carruthersela* cf. *compacta* Gârw. (The corals determined by Dobrolyubova; brachiopods, by Vakhrameev).

2. Red sandstones and conglomerates — 500 m.

3. An interbedding of red arkose sandstones, conglomerates and predominating grey clay shales; the latter contain bands of dark limestones with *Choristites* cf. *yaughukonensis* Chao var. *crassicostata* Semich., *Ch.* ex gr. *bisulcatiformis* Semich. These *Choristites*, collected by M. Shvetzov in 1931 and initially determined as *Spirifer bisulcatus* auct., were re-determined by Semichatova in 1939. Together with *Choristites*, the following were found: *Peticularia* cf. *lineata* Mart., *Athyris concentrica* Buch., *Productus tenuistriatus* Vern.—100 m.

4. Red arcose sandstones and clay shales with intecalations of white gypsum—100 m.

5. Thin-platy, dark, nearly black limestones and calcareo-argillaceous shales containing: *Productus concinnus* Sow., *Pr.* ex gr. *corrugatus* M'Coy, *Pr.* (*Sinuatella*) *sinuata* Kon., *Girtyella indianensis Girty*—50 m.

In both of the above sections the Bashkirian beds are separated from the Upper Visean deposits containing abundant characteristic *Productidae*, by a series of non-fossiliferous rocks, possibly corresponding to the Namurian stage. The same relations between the Visean deposits and the Bashkirian beds are observed in South Ferghana (1) and in the Urals (3). Together with *Choristites* and somewhat higher up the following have been found: *Productsu concinnus* Sow., *Pr.* ex gr. *corrugatus* M'Coy, *Pr. tenuistriatus* Vern.; usually encountered in the Visean and Namurian deposits, but characteristic also of the Bashkirian beds.

The ancient character of the *Productidae* found in the Bashkirian beds was noted by Semichatova (3) for the Urals, and by Vakhrameev (1) for South Ferghana.

South of Lake Son-kul in the Bauralbas range, above the horizon with *Gigantella*, lie non-fossiliferous clay shales containing bands of gypsum (150 m). The upper part of this pack may correspond to the Bashkirian beds. The facts cited above prove the presence in the basin of Lake Son-kul of the Bashkirian beds occupying here a stratigraphical position similar to their position in the sections of South Ferghana and the Urals.

West of Lake Son-kul in the Kavak-tau mountains in the left source of the Minkush river, Sinitzyn described the following section (in ascending order):

1. Red arkose sandstones with bands of thin-pebbled conglomerates, in the upper portion passing into yellow-grey sandstones, overlain by thin-laminated limestones containing: *Choristites* ex gr. *bisulcatiformis* Semich., *Choristites* sp., *Productus* ex gr. *cora* d'Orb., *Pr.* ex gr. *concinnus* Sow., *Athyris* sp. —up to 600 m.

2. Higher up are lying thin-pebbly conglomerates, interbedded with red and greenish-grey sandstones; the latter contain subordinate bands of clay shales and limestones —about 500 m.

From the Upper Visean limestones containing *Productus* (*Striatifera*) *striatus* Fisch., some species of *Gigantella*, the rocks described, assigned by Sinitzyn to the lower portion of the Middle Carboniferous, are separated by a series of limestones (up to 200 m) with *Productus* ex gr. *corrugatus* M'Coy, referred by him to the Namurian stage.

Several times in the pebbles of the conglomerates of the Middle Carboniferous Sinitzyn found micro- and macrofauna of the Visean. In the west on the upper reaches of the Mindjilke and at the place of discharge of the Kokomeran river into the Naryn river, in the Middle Carboniferous deposits appears gypsum amounting to 300 m in thickness. Gypsum has been also found on the northern slope of the Kavak-tau range in the upper courses of Tuyuk-su and Kyzyl-suek rivers.

East of Lake Son-kul in the valleys of the Tuyuk-tor and Kichik-karagoman rivers (southern slope of the Terskey Alatau range) Schultz [4] described brown-red and violet sandstones and shales containing intercalations of reddish and light-grey limestones. The thickness of the beds lying transgressively and with an angular unconformity upon the old pre-Devonian rocks of the metamorphic Kara-kudjir series attains 500 m. In the limestones have been found *Spirifer bisulcatus* Sow., corals—*Bothriophyllum* sp., *Caninia* sp.; the latter, in the opinion of Gorsky who made their determination, are similar to corals from the base of the Middle Carboniferous of China. In a previously published paper we have shown that *Spirifer bisulcatus* Sow. may be distinguished from *Choristites* ex gr. *bisulcatiformis* Semich. only by a study of the arrangement of the dental plates (in *Spirifers* proper they are diverging in the rostral portion, while in *Choristites* they are parallel); therefore, we may question the correctness of Shultz' determination of «*Spirifer bisulcatus*», since the latter upon a study of the dental plates may prove to be a *Choristite*, as it has been more than once the case (e. g. «*Spirifer bisulcatus*» found north of Son-kul by Shvetzov proved to be *Choristite*). The above-said suggests that the above-described deposits of the Terskey Alatau range should be also referred to the Bashkirian beds.

The data presented show that the area of development of the Bashkirian beds occupies the northern Tian-Shan approximately to the latitude of the southern shore of Lake Issyk-kul. The sea which had submerged considerable areas of the northern Tian-Shan in the Upper Visean time probably receded somewhat at the beginning of the Middle Carboniferous epoch. Local elevations occurred at the time producing an erosion of Lower Carboniferous deposits and an appearance of pebbles of limestone with an Upper Visean fauna in the conglomerates of the Bashkirian beds. Stronger elevations causing a marked retreat of the Carboniferous Sea took place after the deposition of the Bashkirian beds, the area of development of which differs little from the area of development of the Visean deposits. On the contrary, the boundary of development of the marine deposits of the Moscovian stage passes considerably further south, in general coinciding with the latitudinal part of the course of the Naryn river.

Previous investigators knowing nothing about the existence of the Bashkirian beds in the northern Tian-Shan, considered that the area of the latter

emerged from under the sea prior to the beginning of the Middle Carboniferous epoch (an exception was formed by the Ketman range, located east of Lake Issyk-kul where marine Middle and Upper Carboniferous sediments were known).

The elevations occurring after the deposition of the Bashkirian beds took place within a wide territory occupying also the area of ranges bordering the Ferghana depression; they considerably lost in intensity to the south ([1]). The elevations caused an erosion of the Bashkirian beds; evidence of this is afforded by the conglomerates lying at the base of the Moscovian stage of North Ferghana. The Bashkirian beds in the territory of the Tian-Shan are represented by different facies: in South Ferghana they are represented by limestones, in North Ferghana by a series of porphyrites, tuffs and shales, and finally in the North Tian-Shan (Kavak-tau mountains, basin of Lake Son-kul, Tereney-Alatau) in the area of immediate proximity from the Caledonian land which was probably located at the place of the present Kirghizian range, the Bashikirian beds are represented by near-coastal shallow-water sediments: conglomerates, sandstones, shales with thin intercalations of limestones and gypsum.

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Received
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Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1939. Volume XXV, № 8

PLANT ANATOMY

POLLEN FORMATION IN DOUBLE FLOWERS OF *MATTHIOLA INCANA* R. BR.

By V. Kh. TUTAJUK

(Communicated by N. I. Vavilov, Member of the Academy, 26. V. 1939)

Matthiola is notably represented by two varieties, (1) the eversporting one and (2) the pure-breeding one. The eversporting variety is the heterozygous for doubleness. Double-flowered individuals of this variety are completely sterile; doubleness is transmitted through single individuals, their seeds always producing both double- and single-flowered plants. The pure-breeding variety is homozygous for singleness; it hardly ever produces doubles.

This paper contains brief results of our study of double flowers of *Matthiola*, which has shown the possibility of formation of microspores (pollen grains) within the petals of a double corolla.

For the investigation were taken buds of double flowers at various ages, beginning with buds which had just started development to those nearly opened. The material was fixed in Carnoy fluid. Sections 12 microns thick were stained with iron-haematoxylin. The study of the young buds in which petals had already started development has shown that archesporial tissue was set in these petals in the same way as in young anthers (Fig. 1). Along with the growth of the petals new portions of archesporial tissue appeared; they were usually disorderly scattered through all the petals of a flower (Fig. 2).

It occured even that several portions of archesporial tissue were present in single petal; with regard to their structure the locules do not differ from those of a normal anther. They are lined, like the normal ones, by tapetum and surrounded by wall cells. The only difference consists in the fact that while the normal pollen locules develop within the tissues of an anther which contains a fibrous layer, the locules contained in petals are often imbedded in the tissue of the petals, the fibrous layer being absent there (Figs. 2 and 3).

All the stages of meiosis are passed normally; however, it is typical of the meiosis in petals that in a single locule quite distinct phases of meiosis may be observed at the same time, as shown in Fig. 4. Prophases, metaphases, etc. are found here to occur simultaneously.

Asynchrony is never observed in normal single flowers, where a given portion of an anther is always found to pass one and the same stage of meiosis.

Turning to the formation of pollen grains, we see that, prior to separation into the individual cells, the pollen tetrads consist of tightly joint cells (Fig. 3); they further separate into constituent cells, on which the exine and intine are formed. Immediately upon the formation of pollen membranes all

the cells of a tetrad strongly grow up and become united with the exine, as if common partition walls were formed between the pollen grains; then the pollen grains begin to grow smaller and separate. The pollen development in normal single flowers takes place in the same way. Mature pollen grains cannot be discharged, as there is no fibrous layer in the petals and they are imbedded deep into the petal tissue; they gradually disintegrate as the bud develops.

Microsporogenesis in petals is characterized by the fact that it is always accompanied at every stage with a certain number of degenerative cells;

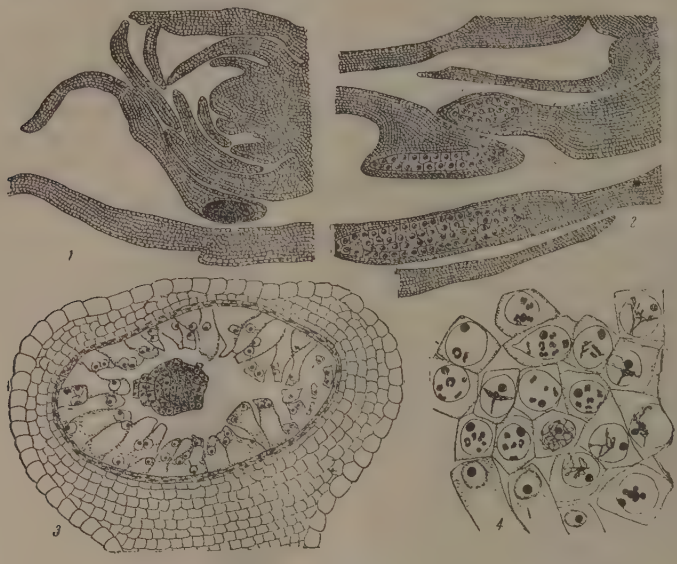

Fig. 1. Archesporial tissue formed in a petal of a young bud.
Fig. 2. Development of the archesporial tissues within a more advanced bud.
Fig. 3. A «locule» in a petal; tapetal layer and closely adjoining tetrads of pollen are visible.
Fig. 4. Asynchronous division in a «locule» of a petal.
All the drawings were made with the aid of Abbé's camera lucida.

the proportion of these cells increases with the progress of meiosis and reaches its maximum at the stage of separation of tetrads into individual cells. Mature pollen grains formed in the petals differ externally in no way from those contained in normal anthers.

As to macrosporogenesis, it may be maintained that there are no traces of such in the double flowers. This may be accounted for partly by the fact that the development of the macrospores in normal flowers laggs behind of the development of the pollen mother cells, so that when mature pollen grains are formed, embryo-sac mother cells just begin to appear in the ovules. In double flowers the formation of mature pollen is almost immediately followed by anthesis, and further growth of petals evidently suppresses the development of the gynaeceum.

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Received
3.VI. 1939.

Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1939. Volume XXV, № 8

PLANT PHYSIOLOGY

YELLOWING AND DYING OF LEAVES IN SOYA AS RELATED TO DAYLENGTH

By G. M. PSAREV

(Communicated by A. A. Richter, Member of the Academy, 25. X. 1939)

Yellowing of leaves is a matter of common knowledge and a wide spread phenomenon in the vegetable world, but in spite of all that the physiological aspect of this process is rather poorly investigated. In physiological literature on the autumn leaf fall the interest has mainly centered about the effect on leaf yellowing of external physiological factors—light, temperature, water supply etc. ([1–4]). Some of the authors ([2,3,5–7]) have come to the conclusion that the factor of prime importance in the yellowing of leaves is the biochemical activity stimulated in the leaf by external and internal conditions of plant's life, rather than the photochemical process initiated by the direct action of light. In recent years the physiological rôle of light in the autumn fall of leaves and in their ageing in general has again been given attention by some workers in photoperiodism ([8–10]).

In order to find out the regularities which may possibly underly the yellowing and dying away of leaves, the author of the present paper has made observation on certain plants while growing them on various daylengths. The purpose of varying the photoperiodic background was to create differences in the development and growth of the cultures tested.

Observations on yellowing of leaves were started in 1931. Two experiments with soya are being reported in brief here. The basic points of the experimental plan are obvious from the annexed tables. And we have moreover to point out that no artificial infection with nodula bacteria (inoculation) either of soil or seeds were made. Sowing was done May 10; the seedlings appeared above ground May 17—19.

Results of Experiments on Leaf Yellowing in Soya. The data on the time of yellowing and falling of leaves in connexion with other phases are given in Table 1.

Curtailing of daylength in the case of soya is seen to delay the process of chlorophyll disintegration, and the yellowing of leaves is therefore slowed down. Most of the varieties given 8- and 10-hour days have retained their green colour of leaf until complete ripeness of their beans. As daylength increases, the yellowing of leaves sets in sooner and is more definitely expressed. On 12-hour daylength three of the five varieties tested had the bulk of their leaves yellowed when ripeness was not complete, but the beans had already started ripening.

On natural and 18-hour daylengths all varieties bore mainly yellow leaves when the beans were far from being completely ripe. The process of intensive

Table 1

Variety	Daylength	Developmental phases				
		Start of flowering	Start of bean ripening	Mass leaf yellowing	Fall of leaf	Complete ripening of beans
Illini	8 hours	June 10—11	July 26—31	None	None	— *
	10 »	» 10—11	» 30	»	»	Nov. 5
	12 »	» 10	» 25	Aug. 19	Aug. 22	— *
	Natural	July 10	Sept. 6—10	Sept. 6	Sept. 14—26	Oct. 2—5
	18 hours	» 30—Aug. 2	Oct. 25—Nov. 6	» 20—Nov. 18	Nov. 10—18	Dec. 6—19
Manchurian cat. No. 693-6	8 hours	June 11	July 30	None	None	— *
	10 »	» 11	» 25	Aug. 2	Aug. 11 (in only one plant)	— *
	12 »	» 11	» 25	—	—	Sept. 2—10
	Natural	June 28—July 2	Aug. 20	Aug. 28	Sept. 14	» 17—26
	18 hours	July 15—17	Oct. 19—21	Sept. 21	Nov. 26	Nov. 20—Dec. 16
Manchurian No. 803	8 hours	June 11	July 30—Aug. 2	None	None	Sept. 26
	10 »	» 11	July 31	»	»	— *
	12 »	» 11	Aug. 2	Aug. 10—16	Aug. 16—21	— *
	Natural	July 5—8	Sept. 10	—	—	Sept. 26
	18 hours	Aug. 5—6	Oct. 21—Sept. 10	Sept. 23—Nov. 10	Nov. 10	Dec. 10—16
Manchurian No. 810	8 hours	June 11	July 24	None	None	— *
	10 »	» 11	» 20	»	»	— *
	12 »	» 12	» 26—Aug. 2	»	»	— *
	Natural	» 21—22	July 31	Aug. 2	Aug. 2	Aug. 22—24
	18 hours	July 1	Aug. 19—26	» 31	Sept. 2—14	Sept. 18—Oct. 9
Manchurian No. 1618	8 hours	June 10	July 22—31	None	None	Sept. 10
	10 »	» 10—11	» 26	Aug. 2—5	—	Oct. 3
	12 »	» 10	» 22	» 2	—	Aug. 21—Sept. 3
	Natural	» 18	Aug 7—16	» 16	Aug.16—22	Aug. 31—Sept. 5
	18 hours	» 28	» 26—Sept. 5	Sept. 10—17	Sept. 14—17	Oct. 9—11

leaf yellowing set in either about the very start of bean ripening or even, in some varieties (Illini, Manchurian 803), when the beans had not yet started ripening.

There is a difference in the character of leaf yellowing among the plants grown on varying daylength. With natural and long days the leaves are yellowing normally in most of the cases, i. e. their green colour turns gradually yellow. Soon after that the leaf blades fall off, sometimes still on their petioles,

* By the time of harvesting the plants bore green leaves and had not come to complete ripeness.

or else, and this is more often the case, they fall with the petioles simultaneously, but are separated from them.

With short days the process of chlorophyll breakdown is often preceded by various phytopathological changes in the leaf. Around the centres of their attacked areas which present spots of brown or similar colour, the breakdown of the chlorophyll takes place and the green pigment turns brown or yellow-brown. After that the blades fall gradually off, but the petioles retain their intense green colour and remain on the plant in this condition for an indefinitely long time. All along the stem of a short-day plant has a fresh appearance and is intensely green, though the beans are often completely ripe at that time. The presence of green leaves on a soya plant of that age is in most of the cases attended by a number of other anomalies in the plant's structure, but they will be described elsewhere.

If the statement which is found to follow from the reported observations is that the yellowing of leaves in soya is related to daylength, nevertheless, the argument being based upon relative data, there is a need for further evidence which would corroborate the statement by absolute figures. This experiment has been done by us and the results obtained are set forth in Table 2.

Table 2

Photoperiods	Developmental phases				
	Start of flowering	Start of bean ripening	Mass leaf yellowing	Fall of leaf	Complete ripening of beans
10-hour day throughout	June 10—11	July 30	None	None	Sept. 5
5 short day followed by long days	» 18—19	Oct. 21—Nov. 18	Sept. 17	Nov. 18	Dec. 6—16
10 short day followed by long ones	» 10—11	Aug. 19—26	Oct. 9—Nov. 6	» 10	» 6
15 short days followed by long ones	» 10	» 11	Nov. 10	» 18	Nov. 6—Dec. 16
20 short days followed by long days	» 11	» 2	None	None	— *
Natural day	July 10	Sept. 6—10	Sept. 6	Sept. 14—26	Oct. 2—5
18-hour day all along	» 30—Aug. 2	Oct. 25—Nov. 6	Sept. 20—Nov. 18	Nov. 10—18	Dec. 6—19
5 long days followed by short days	June 17	Aug. 2	None	None	Sept. 14—Oct. 25
Start with 10 short days	» 21	July 31—Aug. 7	»	»	Oct. 5
Start with 15 short days	» 26—27	Aug. 7—12	Aug. 13—16	Aug. 20	Sept. 26
Start with 20 short days	» 30	» 7—12	» 2—10	» 2—14	» 26—Oct. 2
Start with 25 short days	July 5	» 12—13	» 12—13	» 13—16	Sept. 28—Oct. 14

* By the time of harvesting the plants bore green leaves and had not come to complete ripeness.

With these data at hand we can make the following statements.

The character of the leaf yellowing process and the time when it starts in soya is largely determ ned by the photoperiodic conditions which the plants have been given during a certain early period of their development. If soya plants have received their start on short days, the yellowing of their leaves is delayed considerably (for 11—65 days compared to the normal day in the case of variety Illini). The effect of long days given at the early period of development is opposite. The leaves yellow sooner than in normal day plants (the difference is 21—35 days for Illini).

The conclusions to be drawn from the observations on the yellowing of leaves in soya are as follows:

1. The length of day and night essentially affects the time and character of soya leaf yellowing.

2. If the plants are given short days throughout or for some time during the early period of their development, the process of ageing and yellowing is delayed. In some of the varieties the leaves retain their green colour until complete maturity of beans. And when they yellow later, this process is mainly due to phytopathological phenomena.

3. Another effect of short days is to delay the formation of separating layer in leaf stalks, and after the blades have fallen the stalks remain on the stem for a certain time without losing their intense green colour.

4. If, however, the plants are given long days at the start of development or throughout the vegetation period, their leaves turn yellow before time and fall at the start of ripening or even long before the plant has reached this stage.

5. In long-day plants of soya the leaf stalks, as a rule, fall with the blades simultaneously or follow them soon.

6. All varieties of soya are not alike with regard to yellowing of their leaves. Their difference in this particular case can be made use of in characterizing the soya varieties on a physiological basis for breeding and genetic purposes.

7. Under natural conditions the time and character of soya leaf yellowing is essentially determined by the relation between day and night lengths that prevails during vegetation period.

8. The existence of a definite relation between yellowing of leaves in soya and daylength should be interpreted not only in terms of nutritional variations caused by different light conditions, especially in the supply of nitrogen, but also on the basis of some complex processes which change their course in response to the photoperiodic factor.

9. Among these complex processes of utmost importance is the factor of growth, in particular the quantitative variations of the growth substance in leaf tissues.

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Received 31.X.1939.

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Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1939. Volume XXV, № 8

PLANT PHYSIOLOGY

RÔLE OF PEROXIDASE IN IMMUNITY AGAINST *PHYTOPHTHORA INFESTANS* DE BARY

By A. I. GRECHUSHNIKOV

(Communicated by A. A. Richter, Member of the Academy, 28. X. 1939)

When *Phytophthora* is attacking potato, black necroses make their appearance. This phenomenon has been recorded by De Bary (1) and several other investigators (2). In the case of some other species of *Phytophthora* these dark necroses are also encountered. They are reported in citrus fruits attacked by *Phytophthora cintrophthora* (3), and in the fruits of tomato and potato affected with *Ph. megasperma* (4).

The dark necroses are the first response of the plant to the infection with *Phytophthora*. In the phytopathological practice the resistance of the plant concerned is estimated from how soon the necrosis becomes apparent, and its degree of expression. Resistant plants show a pronounced and quick necrosis upon infection, while in non-resistant plants the dark necrosis is not appreciable. Biochemically the dark necrosis is an oxidation reaction, whereby the substances oxidized are largely of aromatic series ending into darkly stained melanins. The molecule of the substance under oxidation undergoes deep changes in this reaction which is therefore an irreversible one. That such biochemical reactions are possible has been pointed out in the works of Raper (5), Furth and Thallmayer (6) on enzymic oxidation of tyrosin. The oxi-red processes in a normal potato go on, according to Szent-Györgyi (7), through oxidizing and reducing two aromatic compounds, the pyrocatechin and tyrin.

The irreversibility of the reaction may possibly break in response to the infection by *Phytophthora* because of oxidase activation or weakening of the reducing process, and coloured substances will eventually apear as oxidation products.

The rôle of oxidases in the immunity of plants was given attention in the works by Richter (8), Sukhorukov (9) and others. Carboné and Arnaudi (10) believe that the oxidases in the vegetable tissues are protective against infection.

The fact that the outward symptoms of the infection (darkening, necroses) are not equally expressed in the susceptible and the resistant varieties of potato is an incentive to study oxidizing enzymes with reference to the variety and its resistance. During the year 1937 we were engaged in studying the condition of the oxidizing enzyme peroxidase in the susceptible and the resistant varieties of potato with regard to the *Phytophthora*, and the background against which we conducted this study was the action of varying factors.

Resistance of Variety and Action of Peroxidase in Leaves. Enzymic activity in a plant is related to the conditions of its growth and the phase of development. In our experiment the plants were grown in a greenhouse, being thus strictly kept under equal conditions. As to the phasic differences, they were to a certain extent counterbalanced by the fact that many varieties were involved in the test and the samples were taken reiteratedly throughout the experiment. The peroxidase was estimated after the pyrogallol method, centrifuging ([11]) and benzidine method ([12]). Simultaneous testing of several varieties always yielded relative but comparable series of figures.

Now here is the description of the experiment. Peroxidase was estimated in three varieties and one species of potato whose resistance to the attacks of *Phytophthora* had been definitely established: Early Rose, most susceptible; *Solanum Rybinii*, susceptible; Voltman, of medium susceptibility; and No. 8670, a variety resistant to phytophthora. The estimation of the peroxidase was made in the leaves from the middle node previous to the period when the susceptibility to infection with *Phytophthora* was known to reach its maximum (July 29).

The following figures were obtained for the activity of peroxidase expressed as cm^3 of $n/10$ permanganate solution per 1 g of raw leaf weight: Early Rose—14.6, *S. Rybinii*—13.7, Voltman—19.0, No. 8670, resistant—21.2.

The activity of peroxidase was rather high in the *Phytophthora* resistant variety 8670 and in the medium susceptible Voltman, while it was lower in the Early Rose and *S. Rybinii*.

The experiment was repeated on September 16 with three varieties: No. 8670, Early Rose and Smyslovsky (susceptible). The benzidine method of estimating the peroxidase was made use of here. Arbitrary benzidine units per gram of raw leaf weight served to express the peroxidase activity. The results were as follows: Early Rose—70.21, Smyslovsky—93.83, No. 8670—112.81.

Here too the resistant variety showed the highest activity of peroxidase.

Three days later (September 19) the experiment was run over again, but with two varieties only: Smyslovsky and No. 8670. The figures obtained were: Smyslovsky—134.9, No. 8670—183.1.

They are much higher than those in the test of September 16, but the relation between the varieties is preserved.

The estimation of peroxidase in potato tubers during the period of rest (November 1, 1937) involved 3 varieties of varying resistance to *Phytophthora*. The benzidine method was employed and the results were as follows: No. 8670—3.54, Voltman—3.01, Early Rose—2.79.

There was no change in the regularity observed in the previous tests.

We also made observations on the dynamic of the peroxidase in the tubers and these have shown that the activity of peroxidase is lower in them than in the leaves and varies during their storage in winter, being highest toward the time of germination (unpublished data).

The conclusion to be drawn from the figures here referred to (experiments on July 29, September 16, September 19 and November 1) is that there exists a definite relation between the resistance of the varieties to *Phytophthora* and their peroxidase activity; it is most clear that the peroxidase in the leaves and tubers of potato fulfils protective function against infection with *Phytophthora*.

Peroxidase Action in Leaves of Potato as Related to Humidity of Soil. In our preceding communication we were able to show that potato's susceptibility to *Phytophthora* is definitely related to the humidity of soil ([13]). Having then established a rela-

tion between the activity of peroxidase and the resistance to *Phytophthora*, we set ourselves the task to trace the change in the former under conditions of varying soil humidity. The experiment which was a vegetative one, involved two varieties: No. 8670 and Voltman. The peroxidase was estimated by the benzidine method after flowering (September 19). The results are presented in Table 1.

Table 1

Variety	Soil humidity in % of total moisture capacity	Peroxidase activity	
		arbitrary benzidine units per 1 g of raw leaf weight	in %
Voltman	20	278.89	100
»	40	194.95	69.90
»	60	205.95	73.84
»	80	189.43	67.92
No. 8670	20	233.49	100
No. 8670	40	185.93	79.63
No. 8670	60	185.07	79.26
No. 8670	80	137.53	58.90

Here we find the figures of maximum soil humidity (80%) to stand beside those of minimum peroxidase activity (67.92% for Voltman and 58.90% for No. 8670). These results go to confirm the general belief that the danger of infection with *Phytophthora* is greater in the case of excessive humidity, and we may add that the effect of an excessive humidity is not only to favour the development of the fungus, but also to decrease the resistance of the host.

The tubers from the plants grown under varying soil humidity were tested for their content of peroxidase. The results obtained by using the benzidine method are given in Table 2 (exp. on November 3).

Table 2

Variety	Soil humidity in % of total moisture capacity	Activity of peroxidase in arbitrary benzidine units per 1 g of raw weight
No. 8670	20	2.59
No. 8670	40	3.47
No. 8670	60	2.17
No. 8670	80	2.05
Voltman	20	2.63
»	40	2.74
»	60	2.65
»	80	2.54

The content of peroxidase in the tubers is always low and its dependence upon soil humidity is less than in the case of leaves.

Activity of Peroxidase in Potato as Related to Daylength. If days are curtailed, the process of potato-tuber formation is accelerated ([14]). The value of cystoamilase changes, too ([13]), and so

does the susceptibility to affection with *Phytophthora*, as it has been stated on phytopathological observations carried out in the Institute of Potato Industry ([15]). Thus, variety 8670 grown on 10-hour daylength was artificially infected with *Phytophthora* and the result was positive, whereby the fungus obviously formed fruit. Since we had been successful in disclosing a definite relation between the activity of peroxidase and the resistance to *Phytophthora*, we deemed it wise to trace the activity of peroxidase in the leaves of various potato varieties grown on normal (Moscow) and curtailed (8 hours) daylength (Table 3).

Table 3

Date of analysis, 1937	Variety	Daylength	Activity of peroxidase in arbitrary benzidine units per 1 g of raw leaf weight	In %
August 4	No. 8670	Normal	86.29	100
	No. 8670	Curtailed (8 hours)	55.61	64.4
August 7	Early Rose	Normal	50.05	100
	» »	Curtailed (8 hours)	46.56	91.9
September 11	Voltman	Normal	129.0	100
	»	Curtailed (8 hours)	67.0	51.9

With short (8 hours) daylength the activity of peroxidase went down in all the tested varieties, but the decrease was especially conspicuous (by 51.9%) for the late variety Voltman.

The data obtained lead to a conclusion that the photoperiodic conditions are a strong factor in the resistance of potato to the infection with *Phytophthora*.

Activity of Cystoamylase and Peroxidase in Potato Varieties Differing with Regard to Their Resistance to *Phytophthora*. In our previous communication on the rôle of the cystoamylase in the resistance of potato to *Phytophthora* we stated that there is a certain relation between the resistance of the variety and its cystoamilase value. Now we have found that the value of peroxidase is also in play here. The resistant varieties or the resistant conditions of a given variety correspond to a higher value of peroxidase. And it is well to compare these two indices, cystoamylase and peroxidase, in a set of varieties which are not equally resistant to the attacks of *Phytophthora*.

The varieties in Table 4 are arranged in the decreasing order of their cystoamylase value. The tests for cystoamylase and peroxidase were carried on simultaneously, August 27, 1937.

Table 4

Variety	Cystoamylase value	Peroxidase value	Degree of resistance
No. 8670	5.80	124.72	Resistant
Voltman	5.45	94.72	Medium resistant
18883	5.20	74.10	Resistant
19018	5.20	94.17	Slightly susceptible
17776	5.15	82.63	» »
12993	4.85	85.45	» »
Epicure	4.15	79.68	Non-resistant

It will be obvious that the No. 8670, a variety resistant to *Phytophthora*, holds first place in regard to the cystoamylase and the peroxidase value. Last place with respect to the same indices is occupied by the non-resistant variety, Epicure. Varieties of medium or weak susceptibility are intermediate. An exception is formed by variety 18883 which is intermediate with regard to the indices in question, though it has been estimated by breeders as resistant to infection.

It is worthy of note that the Nos. 18883, 19048, 17776 and 12996 referred to as varieties in the table are hybrids, and it is only since 1936 that they have been involved in the test. Their resistance to *Phytophthora* may therefore to a certain degree depart from the estimation. But the resistance of the varieties No. 8670, Voltman and Epicure has been checked in practice, and now it is found to be characterized in a most distinct manner by the values of cystoamylase and peroxidase.

Conclusions. Potato varieties resistant to *Phytophthora* show dark necroses on infection and have their peroxidase more active compared to non-resistant varieties.

When factors unfavourable to the immunity of potato come into play (increased humidity, short days), the activity of peroxidase goes down. The change in cystoamylase values was found when traced through various varieties to go parallel with the respective change of peroxidase values. The cystoamylase values are high in resistant, but low in non-resistant varieties and so are also the peroxidase values. Decisions upon the immunity of a potato plant against *Phytophthora* can be safely based on the cystoamylase and peroxidase indices if the conditions of growing are equal.

Institute of Potato Industry.

Received
31.X.1939.

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Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1939. Volume XXV, № 8

PLANT PHYSIOLOGY

VARIATION OF CYSTOAMYLASE IN POTATO DUE TO DIFFERENT CONDITIONS OF GROWING

By A. I. GRECHUSHNIKOV

(Communicated by A. A. Richter, Member of the Academy, 28. X. 1939)

The resistance of a potato plant to *Phytophthora* varies not only according to the variety, but depends also upon the conditions of growing. The use of manure or mineral fertilizers, conditions of soil, rate of development ([1–3]), daylength—all are important factors influencing the immunity of potato.

It often occurs in the case of hybrids, that the phytopathological estimation given to them by the breeder is upset by some change in external factors, and this is an obstacle in the way of breeding for *Phytophthora* resistant varieties of potato and to their proper estimation. The regularities underlying the changes in the resistance of plants to *Phytophthora* have not been established as yet, because the very nature of this immunity is not clear. In our previous communication ([4]) we made an attempt to interpret the immunity against *Phytophthora* in terms of increased amounts of cystoamylase in resistant plants. Now we are describing the results of our investigation on the dynamic of the cystoamylase in potato plants under the influence of varying daylength and fertilization, both these factors being known to affect immunity against *Phytophthora*.

Change of Cystoamylase Value under the Influence of Daylength. The potato plant is known to be very sensitive to change in daylength ([5–8]). If given curtailed days, the potato undergoes morphological modification, throws off buds (even well flowering varieties do so), forms tubers earlier and its vegetation period is sooner complete. Considering this response of potato to curtailing the daylength, it was of interest to follow the change in the cystoamylase value of various varieties given normal and 8-hour days, but otherwise grown under equal conditions. The results of analysis are presented in Table 1.

Table 1

Date of analysis	Variety	Daylength	Cystoamylase in cm³ of *n*/10 iodine solution	Notes
August 2, 1937	Early Rose	Normal	3.40	8-hour plants failed to flower. The plants from normal day were taken for analysis while flowering
» 2, 1937	» »	8 hours	2.85	
» 2, 1937	Voltman	Normal	5.00	
» 2, 1837	»	8 hours	3.40	
» 2, 1937	No. 8670	Normal	5.85	
» 2, 1937	No. 8670	8 hours	3.60	

The effect of curtailing the daylength was strongly to reduce the amount of cystoamylase in all varieties tested, especially in No. 8670 which is resistant to *Phytophthora*, and the single case of variety 8670 having been infected with *Phytophthora*, while given short days in the experiment described in ([5]), may be explained in terms of this reduction. In our experiment the infection of variety 8670 with *Phytophthora* resulted in necrotic spots having appeared on the leaves, but the fungus failed to develop.

Effect of Mineral Fertilizers upon Cystoamylase Value. The susceptibility of potato to the attacks of *Phytophthora* is influenced by mineral fertilizers. After the latter had been brought to bear on potato culture, there has been a general belief that nitrogen acts unfavourably upon the resistance of this plant to *Phytophthora* and potassium to the contrary increases it ([1]). Iodine, according to Stoclasa ([10]), enhances the storage of sugar in beet, changes its oxidizing system and even morphology. According to Schreven ([11]), the deficiency of manganese in water cultures of potato becomes manifest in light-green chlorotic spots which appear between vessels in the leaf tissue, and in the stem and shoot tips. If the deficient amount of manganese is small, the plant is only slightly affected with chlorosis in the upper part of its stem. With high concentrations of manganese, say 100 mg per litre of nutrient solution, the growth of potato is obviously checked and the plant dies away before ripening. The process of decay proceeds from the lower leaves upwards.

In view of these facts we set ourselves the task of tracing the change in the cystoamylase content of a potato plant under the influence of mineral supply, introduction of manganese and iodine. The experiment was carried on under field conditions. The mineral fertilizers used were: N as ammonium sulphate, P as superphosphate and K as potassium salt (sulphate). 40 kg per ha of each acting principle were introduced in addition to 20 tons of farm manure. If only one mineral was introduced to fertilize the soil, the amount of this acting principle was increased 3 times, i. e. from 40 to 120 kg per ha.

The cystoamylase was estimated in two varieties: Voltman (susceptible) and No. 8670 (resistant). The data are given in Table 2.

Table 2

Date of analysis	Variety	Manuring per ha	Cystoamylase in cm³ of *n*/10 iodine solution
August 9, 1937	No. 8670	Farm manure 20 t + NPK, 40 kg . .	11.00
» 9, 1937	No. 8670	» » + N, 120 » . .	7.45
» 9, 1937	No. 8670	» » + P, 120 » . .	6.75
» 9, 1937	No. 8670	» » + K, 120 » . .	12.55
» 9, 1937	Voltman	» » + NPK, 40 » . .	12.55
» 9, 1937	»	» » + N, 120 » . .	11.35
» 9, 1937	»	» » + P, 120 » . .	11.40
» 9, 1937	»	» » + K, 120 » . .	12.85

Potassium is seen to increase the amount of cystoamylase. This increase is strong in the case of variety 8670 and far less in the case of Voltman. The effect of nitrogen and phosphorus when introduced alone is to reduce the amount of cystoamylase in both cases.

Upon introduction of iodine (4, 8 or 12 mg of KI per 12 kg soil) and manganese (1, 2 or 4 g of $MNSO_4$ per 30 kg soil) into vegetation vessels, no appreciable change in the amount of cystoamylase was observed (Table 3).

Table 3

Date of analysis	Variety	Experimental set	Cystoamylase in cm^3 of $n/10$ iodine solution
September 19	No. 8670	Control	5.20
» 19	No. 8670	KI, 4 mg per vessel	5.75
» 19	No. 8670	» 8 » » »	5.55
» 19	No. 8670	» 12 » » »	5.45
» 19	Smyslovsky	Control	5.55
» 19	»	KI, 4 mg per vessel	5.55
» 19	»	» 8 » » »	4.20
» 19	»	» 12 » » »	5.00
» 16	Early Rose	Control	3.90
» 16	» »	$MnSO_4$, 1 g per vessel	2.70
» 16	» »	» 2 » » »	3.50
» 16	» »	» 4 » » »	3.20
» 16	Smyslovsky	Control	4.00
» 16	»	$MnSO_4$, 1 g per vessel	3.40
» 16	»	» 2 » » »	4.10
» 16	»	» 4 » » »	4.10

Note. The leaves taken for analysis were from the upper node in all cases.

Conclusions. The amount of cystoamylase in potato varies with the conditions of growing. It goes down when the day is curtailed to 8 hours. So far as mineral fertilizers are concerned, an increase in cystoamylase is brought about by potassium when it is made to act singly or in combination with other fertilizers. In response to nitrogen and phosphorus the amount of cystoamylase in potato goes down, but here varietal differences are observed.

Institute of Potato Industry.

Received
31.X.1939.

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Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1939. Volume XXV, № 8

PLANT PHYSIOLOGY

ON THE IMPORTANCE OF SODIUM IN THE PLANT'S LIFE

By G. K. SAMOKHVALOV

(Communicated by A. N. Bach, Member of the Academy, 28. X. 1939)

There exists a divergence of opinions in regard to the importance of sodium in the plant's life. Thus, Kostychev (1), Maier (2) and many others believed that higher plants do not need any sodium at all.

However, many literary data have been accumulated which point to a positive effect of sodium upon the plant. Some of these writers (3–5) think that sodium hinders the formation of poorly soluble potassium compounds and thus facilitates the uptake of this element by the plants. Sodium is thus ascribed to have an indirect effect. Others suppose, on the contrary, that the favourable effect of sodium upon the plant depends on its direct participation in the physiological functions of the plant (6). Russel (7) holds a closely approaching view; he assumes that the effect of sodium depends on the fact that it may partly replace potassium as a nutrient material in many plants.

Finally, Osterhout (8) points out the protective effect of sodium. It was established in a recent work by Butkevich and Maruashvili (9) that sodium salts when present in the surrounding solution in certain concentrations stimulate accumulation not merely of potassium, as shown by Hellriegel (10), but of nitrogen and phosphorus, too.

Taking into account the great divergence of ideas as to the importance of sodium, we have found it necessary to do some research in this direction. With this aim in view we have conducted a number of experiments, in which was studied the effect of sodium when given to the plants instead of potassium.

In the first series of experiments substitution of sodium for potassium was done at the beginning of a given developmental stage, and the plants were brought up under the changed conditions of nutrition till the close of their cycle; in the second series of experiments elimination of potassium and its replacement by sodium was done only for the periods during which individual stages of development were passed; during the rest of their life cycle the plants were grown in a nutrient solution of a normal composition.

The aim of these experiments was to follow up the effect of sodium on the behaviour of the plants at various periods of their life. Experiments were done on the summer barley, variety «Wiener». Plants were grown in the nutrient solution of Hellriegel. Plants which were grown in the complete nutrient mixture during the whole life period served as control.

When sodium was substituted for potassium, the plants were given corresponding amounts of NaH_2PO_4 and NaCl instead of KH_2PO_4 and KCl, respectively: in order to eliminate potassium, $CaHPO_4$ was substituted for KH_2PO_4 and KCl. In so far as the nutrient mixture was dissolved in distilled water, plants were given also the microelements: B, Mn, Al, Cu and I. Experiments were run in the summer of 1938. Plants of the first series were planted into the solutions on May 21, those of the second—on May 26 (Table 1).

Table 1

Effect of Eliminating K for a Long Time and of its Replacement by Na

Variant	Air dry weight in g per one plant			
	Total mass	Roots	Over-ground mass	Corn
Control	8.564	0.566	4.722	3.276
No K from the beginning of tillering	1.242	0.250	0.992	0.000
» » » » » » stalking	6.128	0.430	3.714	1.984
» » » » » » earing	7.112	0.473	3.909	2.730
» » » » » » milky ripeness	7.393	0.500	4.070	2.828
» » » » » » waxy »	7.720	0.540	4.230	2.950
— K + Na from the beginning of tillering	3.418	0.470	2.948	0.000
— K + Na » » » of stalking	7.935	0.630	4.720	2.585
— K + Na » » » of earing	8.546	0.640	4.800	3.106
— K + Na » » » of milky ripeness	8.331	0.600	4.601	3.130
— K + Na from the beginning of waxy ripeness	8.238	0.580	4.454	3.204

Elimination of potassium at any stage of development had a negative effect upon the plant's growth. Moreover, the longer the plants remained in the solution containing no potassium, the stronger was the negative effect.

Far better proceeded the accumulation of organic substance in plants which were given sodium instead of potassium, from the stage of tillering onwards. Nevertheless, the plants suffered depression in this case, too, which could be deduced from their precocious maturity (Table 2).

Table 2

Variant	Date of full maturity of the plants		
	+ K	— K	—K +Na
Control	31.VII	—	—
From the beginning of tillering	—	13.VII	25.VII
» » » » stalking	—	25.VII	26.VII
» » » » earing	—	28.VII	28.VII
» » » » milky ripeness	—	29.VII	29.VII
» » » » waxy ripeness	—	31.VII	31.VII

The data of the experiment (Table 3) also show that in case potassium is temporarily excluded and replaced by sodium, whatever the variant of the

experiment, plants produce lower yield, both of total mass and corn, as compared with the control; however, like in the experiments of the first series, the dry weight of the total mass and of the corn proved higher when potassium was replaced by sodium than in those cases when potassium was simply excluded, no sodium being substituted.

1. When potassium is eliminated during the period of development of the plants of barley («Wiener») prior to tillering, and when replaced

Table 3

Effect of K Elimination and of its Replacement by Na at Different Phases of the Plant's Development

Variant	Air dry weight in g per one plant		
	Total mass	Vegetative mass (roots, stems and leaves)	Corn
Control	6.539	4.642	1.897
No K from the beginning of tillering till the beginning of stalking	4.778	4.248	0.530
No K from the beginning of stalking till the beginning of earing	3.670	3.423	0.247
No K from the beginning of earing till the beginning of milky ripeness	5.153	4.160	0.993
No K from the beginning of milky ripeness till the beginning of waxy ripeness	4.234	3.617	0.617
No K from the beginning of waxy ripeness till the close of the life period	5.290	4.200	1.090
—K +Na from the beginning of tillering till the beginning of stalking	4.197	3.640	0.557
—K +Na from the beginning of stalking till the beginning of earing	5.257	3.877	1.380
—K +Na from the beginning of earing till the beginning of milky ripeness	4.997	4.016	0.981
—K +Na from the beginning of milky ripeness till the beginning of waxy ripeness	5.003	3.879	1.154
—K +Na from the beginning of waxy ripeness till the close of the life period	5.597	4.214	1.383

by sodium in particular, general decrease of productivity and underdevelopment of the reproductive organs is the result in all cases.

2. Sodium cannot replace potassium in the nutrient solution. However, when sodium is introduced at a period after tillering instead of potassium which was present until tillering set in, the plants develop considerably better than in absence of potassium and sodium. A normal development of reproductive organs was noted here, too. This depends on the fact that potassium which is absolutely essential for the normal development of the plants had enough time to enter the plants and was better utilized during the later development of the plants in solutions containing no potassium.

3. The positive effect of sodium given instead of potassium depends on its indirect action upon the life activities of the plants, owing both to more

favourable conditions of the ionic composition of the nutrient solution and, obviously, to a stimulated utilization of potassium in the plant organism.

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Received
27.VIII.1939.

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Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1939. Volume XXV, № 8

PLANT PHYSIOLOGY

CONTENT OF CHLOROPHYLL IN WHEAT AS RELATED TO DEVELOPMENT

By A. A. ZAITZEVA

(Communicated by A. N. Bach, Member of the Academy, 28. VII. 1939)

The object of the present work was to trace the variation of chlorophyll content in wheat in connexion with vernalization and development. The investigation involved two biologically related soft wheats: a spring variety—*lutescens* 062, and a winter variety—*lutescens* 329. The latter was tested in two sets—vernalized and unvernalized plants. The unvernalized plants were in the stage of tillering until the end of the experiment, being thus always ready to serve as controls when the relation between the development of plants and their content of chlorophyll was followed. The wheat was grown out-of-doors in vessels being liberally supplied with water. Chlorophyll was estimated in alcohol extracts with the spectrocolorimeter of Lubimenko. Throughout this work the amount of chlorophyll is expressed in mg of crystalline chlorophyll per 1 g of green leaf weight. The development of plants was not alike in all the experimental sets. The spring variety *lutescens* 062 was the most advanced in development being somewhat ahead of the vernalized plants of *lutescens* 329, while the unvernalized plants continued tillering until late in the spring. Now let us set forth the results obtained. Planting was done May 22, and that is the day from which the age of the plants is counted. Until the outset of tillering the order of the leaves is counted from below. Beginning with the age of 29 days, the leaves are counted from the top, the upper, fully developed leaf being reported as the first leaf. In the table the ordinal numbers of leaves are given in parentheses.

Examination of the data obtained reveals above all that in winter wheat *lutescens* 329 which was throughout summer in the stage of tillering, the content of chlorophyll amounted to a certain value toward the outset of full tillering and remained at it until late in the autumn. Some fluctuations around this constant value can be explained in terms of individual differences between the leaves analyzed, connected with their age and varying external conditions.

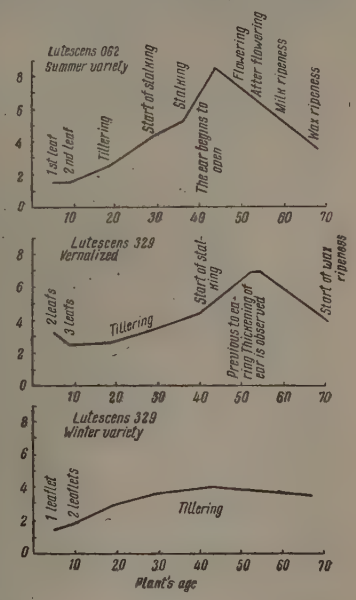
Another point to note here is that every new leaf which appeared on the tillering winter plants during summer had nearly a constant content of chlorophyll at the time, when it completed development and until senile modifications set in, and this irrespective of the age of the plant at that time or the order of the leaf concerned.

Quite different was the picture obtained with the spring and the vernalized winter wheat. Here the content of chlorophyll increased continuously as the plants passed the successive phases of growth and new leaves developed on them. Every new leaf at the moment of its full development had a higher

Lutescens 062—spring variety				*Lutescens* 329—vernalized				*Lutescens* 329—winter variety			
Age in days	Phase of growth	Chlorophyll content		Age in days	Phase of growth	Chlorophyll content		Age in days	Phase of growth	Chlorophyll content	
		1st exp.	2nd exp.			1st exp.	2nd exp.			1st exp.	2nd exp.
5	1st leaf	1.45 (1)	1.5 (1)	5	Second leaf started development	3.11 (1)	3.11(1)	5	1st leaf	1.55 (1)	1.8 (1)
						2.515(1)					
9	2nd leaf	1.639(1)	1.67(1)	9	3 leaves	1.956(2)	—	9	2nd leaf	1.816(1)	—
		1.565(2)	1.45(2)			1.565(3)				1.632(2)	
18	Outset of tillering	2.6 (2)	2.6 (2)	18	Outset of tillering	2.6 (2)	2.6 (2)	18	Outset of tillering	2.85 (1)	—
29	Outset of stalk-formation	4.0 (1)	3.91(1)	29	Full tillering	3.33 (1)	3.33(1)			3.24 (2)	
		4.0 (2)	3.91(2)			3.5 (2)	3.75(2)				
		3.33 (3)	3.5 (3)	42	Stalk-formation	3.93 (1)	3.87(1)				
						5.21 (2)	5.1 (2)	29	Full tillering	3.33 (1)	3.33(1)
37	Stalk-formation	4.7 (1)	4.0 (1)			4.44 (3)	4.44(3)			3.5 (2)	3.5 (2)
		5.21 (2)	5.21(2)	45	Stalk-formation. The last leaf failed to develop. No swelling	4.61 (1)	—			3.5 (3)	3.5 (3)
		5.59 (3)	4.7 (3)			5.1 (2)		42	Tillering	4.0 (1)	—
		4.28 (4)	3.63(4)			4.36 (3)				4.0 (2)	
42	Expiration of stalking. Upper leaf completely unfolded. Swelling with the spike is noticeable	5.33 (1)	5.21(1)	53	Swelling with the spike noticeable	5.85 (1)	—			4.0 (3)	
		5.25 (2)	5.25(2)			5.71 (2)					
		4.52 (3)	4.52(3)	55	Spike starts opening before heading	6.31 (1)	6.66(1)	45	»	4.0 (2)	—
		3.42 (5)				4.89 (2)	5.85(2)			3.87 (3)	
				59	Spike half opened	6.48 (1)	—				
45	Spike not yet open	5.35 (1)	—			5.25 (2)		53	»	3.28 (1)	—
		5.71 (2)				4.44 (3)				3.15 (2)	
—	Spike starts opening	7.74 (1)	—	67	Flowering	5.59 (1)	5.33(1)				
		7.5 (2)				4.52 (2)	4.89(2)	55	»	3.75 (1)	—
53	Flowering	5.71 (1)	6.0 (1)			2.1 (3)				3.93 (2)	
		5.1 (2)	5.0 (2)	73	Period after flowering	4.28 (1)	—				
55	Period after flowering	5.59 (1)	—			4.0 (2)		59	»	3.38 (1)	—
		3.93 (2)		—	First ripeness sets in	4.61 (1)	—			3.80 (2)	
59	First («milky») ripeness	5.25 (1)	5.21(1)			3.75 (2)		-		3.42 (3)	
		4.44 (2)		—	First repeness	4.52 (1)	—				
67	Not quite mature («waxy» ripeness)	3.63 (1)	—			2.66 (2)		67	»	3.47 (1)	—
		2.12 (2)		—	Start of «waxy» ripeness	3.42 (1)	—				
						1.84 (2)		73	»	3.28 (2)	—

content of chlorophyll compared to the preceding leaf. Its highest value the concentration of chlorophyll attains in the lest leaf on the stem which covers he spike, and this by the time when it begins to open and get free from its covering leaf. It is at this period that we sometimes found up to seven or even more mg of crystalline chlorophyll per 1 g of green leaf weight. During further development the chlorophyll content in the leaves keeps decreasing, slowly at first, and then more and more quickly. Toward the beginning of waxy ripeness it is again no more than 3.5 mg in the upper leaf and 2 mg in the second leaf from above.

The dependence of the chlorophyll content upon the development of the plant is clearly seen in the figure, in which the curves of chlorophyll concentration as function of phasic development are plotted for the upper leaves highest in chlorophyll from the three wheats under investigation: spring *lutescens* 062, vernalized *lutescens* 329, unvernalized winter *lutescens* 329. The relation is especially conspicuous in the case of tillering winter wheat. Analogous results were obtained with the variety *erythrospermum*. Its first leaf contained 5.85 mg of chlorophyll when heading set in, while at the outset of stalking only 3.87 mg were present in the first leaf from above, though it was perfectly developed. Samples were taken simultaneously from the plants planted at different dates.



I should like to dwell here upon a certain period in plant's life when it is going to head or is heading, since the content of chlorophyll is a maximum at that time.

Viewed with regard to some physiological properties this period was more than once reported by investigators as a quite particular one. Many of them came to the conclusion that the plant when going to head or heading is especially sensitive to insufficient supply of water. They consider this period as critical in respect of water requirement.

In an unpublished work of 1937 Gerber observed a maximum rate of gas metabolism—respiration and photosynthesis—during this period in a number of plants. Still earlier Popova and Kukolkin (1) found the wheat to be higher in sugar on flowering than on tillering. Savostin and Okunzov (2) reported considerable increase in the catalase and amylase content toward the time of heading.

Lastly, in our own work of 1936 not yet published either, an abundant material has been obtained which brings into evidence that it is by this very time that the photosynthetic apparatus of wheat shows increased sensitivity to water deficiency. Even a short drought can strongly and for a long time destroy the assimilating activity of wheat, if it falls within the period just before heading. During nearly a fortnight after it had been experienced by a plant going or starting to head, there was still observed a disturbance in the work of the assimilating apparatus and a very poor assimilation of carbon dioxide compared to controls. If however as short a drought occurred at other stages of wheat's development, the assimilation apparatus was by far not so strongly affected, and the normal photosynthetic activity was soon

restored, so that in a number of cases the affected plants even showed during a certain interval an increased rate of photosynthesis compared to the period before drought. There is also some evidence that the plants going to head are more responsive to temporary overlasting than are young plants.

From all these data it is apparent that physiologists must give their special attention to this period in plant's life.

If we turn to the physiology of the animal organism, we see that the time of sexual ripening is a period of reconstruction of the organism which then exhibits a series of physiological peculiarities and a high sensitivity to unfavourable influences. It is just when the sexual organs are ripening rather than when their primordia are being initiated in the animal organism, that an array of essential modifications are observed. And it is only natural to suppose that in a plant organism, too, the period of sexual ripening, when the reduction division sets in and the sexual cells are forming, is attended by a number of physiological modifications and peculiar features. Corroborative evidence of this supposition is afforded by the fact referred to here. This period needs thorough investigation, since it is a crucial point in plant's life.

But let us turn back to the content of chlorophyll. Investigations by Griffon ([3]), Lubimenko ([4]), Willstätter and Stoll ([5]) have shown that for the photosynthesis to run its normal course there is no need of very high content of chlorophyll. Therefore the photosynthetic requirement can by no means account for such high concentrations of chlorophyll as were recorded by us and still earlier by Kuzmenko ([6]) in the upper leaves of wheat plants starting to head.

That those high concentrations should nevertheless be a matter of fact and preserved by the various varieties as a stubborn character, is likely to have some special biological meaning and justification. The supposition which suggests itself is that the significant rôle fulfilled by the chlorophyll in the development of a vegetable organism is not only that of a factor indispensable for the processes of CO_2 assimilation to take place. It is well to remember a recent work by Katunsky ([7]), in which it is stated that the relative effectiveness of the photoperiodic action of various wave-lenghts is directly dependent upon the degree of their absorption by green leaves.

Very likely the fact that the leaves nearest to the spike are the highest in chlorophyll and besides endowed with an increased power of light absorption bears upon the ratio of ripening of sexual organs, and with that upon the rate of development of the entire plant. It appears therefore to be time now for attacking the problem as to the rôle of the chlorophyll in plant's development.

Conclusions

1. There is no doubt about the content of chlorophyll being definitely related to the development of wheat.

2. The amount of chlorophyll goes up as the plant develops. The leaves increase in chlorophyll in the order they appear on the stem. The concentration of chlorophyll is a maximum in the last leaf when it no longer envelops the spike. Toward that time the content of chlorophyll in some of the wheat varieties is exceedingly high—7 and more mg of crystalline chlorophyll per 1 g of green leaf weight. Further on, as the leaves grow older their content of chlorophyll goes down more and more quickly, so that it is only half when the plant approaches the full ripeness.

3. The variation in the content of chlorophyll here described are related to the development of the plant rather than to any external changes. This is convincingly proved by the fact that the winter wheat plants which remai-

ned at the stage of tillering throughout the experiment had their leaves with nearly constant content of chlorophyll during the period from complete tillering until the end of vegetation.

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Received
31.VII.1939.

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Comptes Rendus (Doklady) de l'Académie des Sciences de l'URSS
1939. Volume XXV, № 8

PALEONTOLOGY

CONTRIBUTION TO THE TAXONOMY OF SARMATIAN GASTROPODS

By V. KOLESNIKOV

(Communicated by A. D. Arkhangelsky, Member of the Academy, 28. X. 1939)

For over a century, beginning from Eichwald's times (1), many Sarmatian species have been commonly held to belong to the genera *Trochus*, *Buccinum* and *Bulla*. The separation of these genera from amongst the Sarmatian mollusks is not warranted, either on morphological, or on genetic evidence (as far as origin is concerned).

The Sarmatian fauna lived in an isolated basin. There is nothing enigmatical about its origin. The pre-Sarmatian, Konka brackish-water sea was invaded by numerous marine species; when the sea became isolated again, part of them died out, and those that remained gave rise to the peculiar endemic Sarmatian fauna which after a relatively short period of prospering became extinct, toward the close of the Sarmatian. Their extinction had been caused by a sharp change in the environmental conditions due to the strong freshening of the basin.

It is quite obvious that in working out a systematic arrangement one should not ignore geological history, and records of the latter show that none of the enumerated three genera inhabited the Konka basin. Furthermore, it should be taken into consideration that the Sarmatian mollusks thriving under conditions of an isolated sea could have strongly diverged from their Konka ancestors, which was actually the case. Therefore when discussing the taxonomic position of some or other Sarmatian species it is necessary to know the history of its development. This is the only way to class the Sarmatian mollusks among universally adopted genera.

The history of the development of Sarmatian molluscs had already been given attention (2), hence in the present communication I shall be concerned with the conclusions—the taxonomy. In the lists of species, after the description of each genus, section etc., old generic designations are given for proper guidance.

Family *Trochidae*

Almost all the Sarmatian *Trochidae* are commonly assigned to the genus *Trochus*, however, the latter is marked by far larger shells, moreover, it does not occur in the Middle Miocene beds, including those of Konka. At the present time this genus inhabits the Indian and Pacific oceans, whereas the Sarmatian species have descended from the *Gibbula* and *Calliostoma* of the Konka beds.

Genus *Gibbula* Risso 1826. The living representatives of this genus have a wide range of distribution, excepting the Arctic and Antarctic regions; fossils are found in Tertiary and Quaternary beds. Sarmatian bra-

ckish-water *Gibbula* show great diversity. They appear to fall into several sections. Section *Robur* n. sect. (type *Trochus robur* David). Lower Sarmatian representatives of this section—*G. angulata* (Eichw.)—make the nearest approach to the typical *Gibbula*, but the Middle Sarmatian species depart quite sharply from them. *Trochus angulatus* Eichw., *T. albomaculatus* Eichw., *T. subbalatro* Koles., *T. urupensis* Usp., *T. robur* David., *T. stavropolianus* Kudr. Section *Rollandiana* n. sect. (type *Trochus rollandianus* d'Orb.) is very conspicuous among the Middle Miocene and Sarmatian *Gibbula* by its broad umbilicus and low whorl. The oldest forms have a faint keel, whereas species which had evolved during the time of extinction of Sarmatian mollusks, possess a sharp keel. *Trochus subprosiliens* Sinz., *T. rollandianus* d'Orb., *T. margaritoides* Sinz., *T. valvatoides* Sinz., *T. pseudorollandianus* Koles., *T. chersonensis* Barb., *Turbo beaumonti* d'Orb. Section *Pictiformes* n. sect. (type *Monodonta mamilla* Andrz.) is characterized by a deep suture, presence of a suture facet and a faint keel. In the Sarmatian deposits the section is represented by 2 species: *Gibbula mamilla* (Andrz.) and *G. noduliformis* (Sinz.); both species without umbilicus. The Konka shells have a fissuriform umbilicus.

Genus *Calliostoma* Swainson 1840. At present representatives of this genus live almost in all the seas. Fossil *Calliostoma* are particularly abundant in Sarmatian beds; in the Konka beds they occur less frequently. During the Sarmatian, alongside of *Calliostoma* s. s. several sections are distinguishable sharply differing from one another. Some groups deviate to such an extent from the typical *Calliostoma* as to be more appropriately regarded as subgenera (*Sinzowia* and *Kishinewia*) or even, like for instance, the thick-walled form, allied to *Calliostoma podolica* (Dub.)—as a separate genus *Barbotella*. Section *Calliostoma* s. s. unites a group of related species: *Trochus podolicoformis* Koles., *T. insperatus* Koles., *T. pseudohommaire* Koles., *T. marginato-sinzowi* Koles., *T. beaumonti* d'Orb., *T. sulcatopodolicus* Koles., and a few species whose relationships with those enumerated above are obscure: *T. longomarginatus* Koles., *T. philippi* Sinz., *T. podolicoworonzowi* Sinz. Section *Sarmates* n. sect. (type *Trochus sarmates* Eichw.) includes very diverse but related species, characterized by a more or less developed median keel: *Trochus sarmates* Eichw., *T. papilla* Eichw., *T. cordierianus* d'Orb., *T. podolicus* Dub., *T. laevigatopodolicus* Koles., *T. hommairei* d'Orb., *T. praearmavirensis* Koles., *T. armavirensis* Koles., *T. caucasicus* Eichw., *T. blainvillei* d'Orb., *T. subblainvillei* d'Orb. Section *Feneoniana* n. sect. (type *Trochus feneonianus* d'Orb.). The Lower Sarmatian representatives possess a pointed basal keel and sharp spiral ribs; in the Middle Sarmatian ones both keel and ribs are gradually dying out. *T. praefeneonianus* Koles., *T. feneonianus* d'Orb., *T. angulatosarmates* Sinz., *T. pseudoangulatus* Sinz., *T. angulatiformis* Sinz., *T. kishinevensis* d'Orb. Section *Anceps* n. sect. (type *Trochus anceps* Eichw.) unites numerous species, possessing relatively small and quite thin-walled shells with flat base and whorls. All these species, except *Trochus subturriculoides* Sinz., lived only on Bryozoan reefs and in their immediate proximity. *T. subturriculoides* Sinz., *T. phasianellaeformis* Sinz., *T. subanceps* Sinz., *T. elegantulus* Sinz., *T. minutus* Sinz., *T. zonatopunctatus* Sinz., *T. bessarabicus* Sinz., *T. subsigaretus* Sinz., *T. anceps* Eichw., *T. marginatus* Eichw., *T. costatopapilla* Koles., *T. praecurvilineatus* Koles., *T. curvilineatus* Sinz., *T. suborbignianus* Sinz., *T. turriculoides* Sinz., *T. pageanus* d'Orb., *T. adelae* d'Orb., *T. obustus* Koles., *T. pseudomimus* Sinz., *T. perfidus* Koles.

Subgenus *Sinzowia* Kolesnikov 1935. Elongated turreted shell with slipping whorls, sculptured by spiral striae: *Sinzowia elatior* (d'Orb.), *S. intermedia* (Sinz.), *S. striatotuberculata* (Sinz.).

Subgenus *Kishinewia* Kolesnikov 1935. Long turreted and needle-shaped shells with smooth whorls: *Kishinewia bessarabica* (d'Orb.), *K. elongatissima* (d'Orb.).

Genus *Barbotella* Cossmann 1918. Differing from *Calliostoma* in convex rounded whorls and very weak keel. *Barbotella* recalls *Turbo*, however has none of its calcareous opercula. *Barbotella omaliusii* (d'Orb.), *B. laevigatoomaliusii* (Koles.), *B. hoernesi* (Barb.), *B. grossocostata* (Rad. et Pavl.), *B. intermedia* (Rad. et Pavl.).

Family *Nassidae*

Genus *Duplicata* Zhizhchenko in lit. The Sarmatian *Nassidae* are usually referred to the genus *Buccinum* which does not live in the Mediterranean region, nor did it exist there in Tertiary times. The Sarmatian species are indubitably derived from *Nassa*, but under the conditions of an isolated basin have strongly diverged from them. We should therefore welcome their ranking as a separate genus, which was done by Zhizhchenko in his paper «Konka Mollusks» (Paleontology of the USSR). Section *Duplicata* s. s. comprises a fairly large number of mostly Lower Sarmatian species: *Buccinum duplicatum* Sow., *B. seminovale* Koles., *B. mirandum* Koles., *B. opinabile* Koles., *B. superabile* Koles., *B. lymnaeiformis* Koles. and, possibly, *B. subspinosum* Sinz., *B. orgeevense* Koles., *B. triformis* Koles., *B. ignobile* Koles., *B. gricivense* Koles., *B. kishinevense* Koles. Section *Duplicatula* n. sect. (type *Buccinum duplicatum-verneuillii* Sinz.) unites shells usually ornamented with rows of rounded tubercles. However, in some species of the Sarmatian mollusks at the time of extinction the tubercles begin to be replaced by spiral ribs and disappear almost entirely. *Buccinum duplicatum-verneuillii* Sinz., *B. duplicatum-hörnesi* Sinz., *B. jacquemarti* (d'Orb.), *B. gracile* Sinz., *B. pseudogracile* Koles., *B. verneuillii* d'Orb. Section *Omnivaga* n. sect. (type *Buccinum omnivagum* Koles.) is characterized by the presence in the lower part of the whorl (at the columella plication) of a distinct row of tubercles. *Buccinum omnivagum* Koles., *B. torpidum* Koles., *B. nasutum* Koles., *B. duplicatum-haueri* Sinz. Section *Corbiana* n. sect. (type *Buccinum corbianum* d'Orb.) is characterized by obliquely set longitudinal ribs. *Buccinum corbianum* d'Orb., *B. fraudulentum* Koles., *B. impexum* Koles. Section *Dissita* n. sect. (type *Buccinum dissitum* Dub.) includes shells having their ultimate whorl armed at the base with a broad ridge. *B. dissitum* Dub., *B. daveluinum* d'Orb.

Genus *Akburunella* Kolesnikov 1935. Under this name were described shells without the row of tubercles below the suture, occurring in relatively deep-water beds of the Sarmatian. From *Duplicata* they broke away as early as in the Konka time (²). *Akburunella akburunensis* (Andrus)., *A. nefanda* (Koles.), *A. inflata* (Sinz.), *A. egorlykensis* (Koles.), *A. bosphorana* (Andrus)., *A. stavropolensis* (Kudr.), *A. maturatis* (Koles.), *A. multicostata* (Kudr.), *A. scalaris* (Andrus.), *A. tscharnozkii* (Kudr.), *A. leioconcha* (Usp.).

Family *Scaphandridae*

Sarmatian *Scaphandridae* were usually referred to the genus *Bulla*, whose modern representatives are placed in an entirely different family entitled *Bullaridae* (⁴). The Sarmatian species belong to 2 genera: *Acteocina* Gray (=*Tornatina* A. Adams) and *Cylichna*.

Genus *Acteocina* Gray 1897. Representatives of this genus show a very peculiar groove-like suture. *Bulla lajonkaireana* Bast., *B. reseniensis*

Koles., *B. okeni* Eichw., *B. inflexa* Baily, *B. urupensis* Koles., *B. sinzowi* Koles., *B. eichwaldi* Koles., *B. intacta* Koles.

Genus *Cylichna* Loven 1846. Suture simple, upper portion of the whorls rounded. The method of subdivision of the modern species into sections according to the character of the umbo and shape of the whorls cannot be applied in the case of the fossil material of the Sarmatian. The Sarmatian *Cylichna* constitute one group of related species, the development of the group being rather clearly traceable. The most ancient of them are shells with submerged umbones which are gradually emerging, this being accompanied by a modification of the shape of the whorls. During the time of extinction of Sarmatian mollusks, the umbo begins to sink; to be sure, it is rather the penultimate whorl that sinks, and in the center of the funnel there is appearing the umbo projecting like a spire. *Bulla melitopolitana* Sok., *B. pupa* Eichw., *B. gerassimovi* Dan., *B. enikalensis* Koles., *B. usturtensis* Eichw., *B. gerassimovi* Dan., *B. enikalensis* Koles., B. *usturtensis* Eichw., *B. pseudourupensis* Koles., *B. plicatilis* Sinz., *B. monstrosa* Sinz.

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Received
28.X.1939.

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